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IRON AND STEEL ENGINEER

VOL. XIII NOVEMBER • 1936 NO. XI

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New! WIDE STRIP REELS

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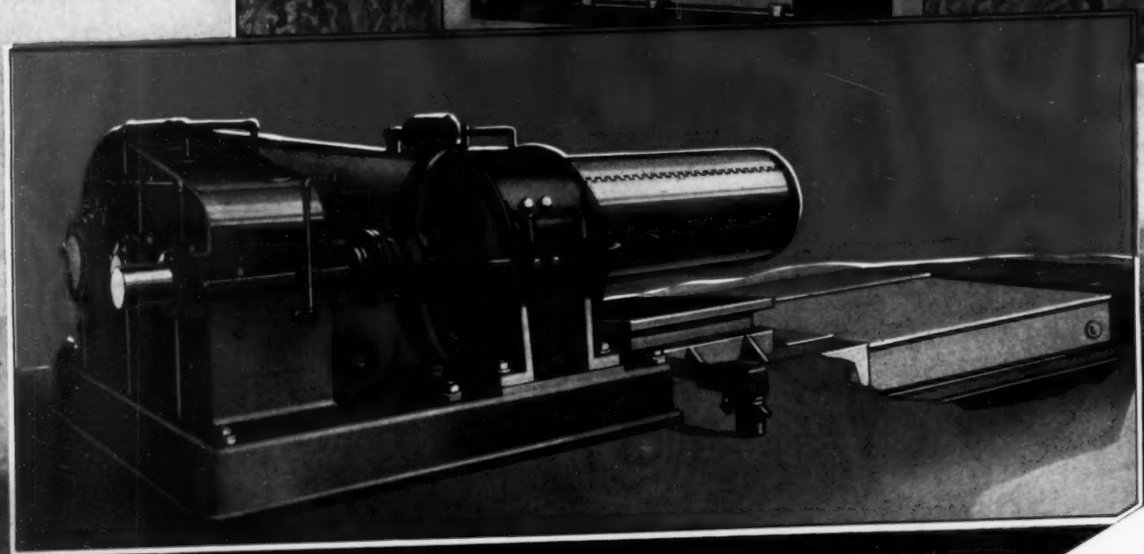

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THE WEAN ENGINEERING CO., INC.
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COMING MEETINGS AND PAPERS

BIRMINGHAM DISTRICT SECTION

November 28, 1936

Thomas Jefferson Hotel, Dinner 3:45 P.M.
Birmingham, Alabama Meeting 8:00 P.M.

"Modern Material Handling" by D. F. O'Donnell, District Manager, Edison Storage Battery Company, St. Louis, Mo.

CHICAGO DISTRICT SECTION

Christmas Party—Date to be announced later.

CLEVELAND DISTRICT SECTION

November 20, 1936

Cleveland Engineering Society Room,
Cleveland, Ohio Meeting 8:00 P.M.

"Modern Practice in Steam Generating Plants" by A. G. Darling, General Electric Company, Schenectady, N. Y.

PHILADELPHIA DISTRICT SECTION

December 5, 1936

Engineers Club of Philadelphia, Dinner 6:00 P.M.
1317 Spruce Street, Meeting 8:00 P.M.

"Fitting the Weld to the Job" by W. E. Crawford, Engineer in Charge of Welding Activities, A. O. Smith Corporation, Milwaukee, Wisconsin.

PITTSBURGH DISTRICT SECTION

November 21, 1936

Cardinal Room, Dinner 6:30 P.M.
William Penn Hotel, Meeting 8:00 P.M.

"Recent Turbine Developments for Special Reference to Applications in the Steel Industry" by C. B. Campbell, Turbine Engineer, Westinghouse Elec. & Mfg. Company, South Philadelphia, Pa.

NATIONAL MEETINGS

February 25, 1937
Youngstown, Ohio

Technical Sessions and Inspection Trip to Youngstown Sheet & Tube Company, Campbell Works.

SPRING ENGINEERING CONFERENCE

April 28-29, 1937 Buffalo, New York

April 29, 1936

Inspection trip to Hot and Cold Strip Mills, Bethlehem Steel Company.

Technical Sessions, Hotel Statler

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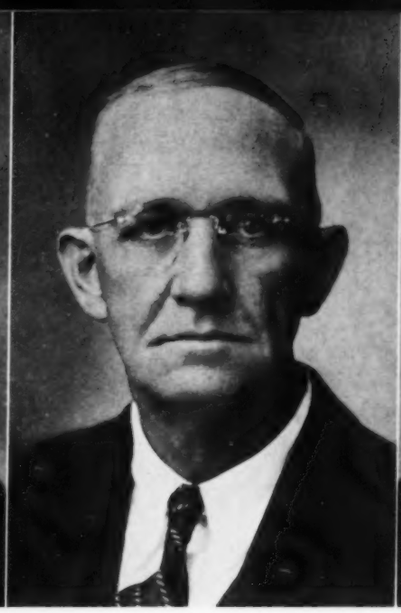

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Lubrication OF STEEL MILL EQUIPMENT

By C. J. KLEIN, Chief Engineer
Weirton Steel Company
WEIRTON, W. VA.

C. J. KLEIN

Presented before the Annual Convention of the A. I. & S. E., Detroit, September 22 to 25, 1936

▲ IN the preparation of these notes, the writer is considering only such cases as involved operating difficulties which were overcome through the correction of mechanical defects. These mechanical defects are not of a nature uncommon to the general run of equipment. In other words, the steps which were taken to correct these troubles are the same as have been taken in numerous other cases. It has not been attempted to take any freak complaints, neither does this memorandum deal with equipment which is unusual and unlikely to be met in the general run of steel mill operation.

PRIME MOVERS—STEAM TURBINES

Steam is generated in practically every steel mill operation, and there are very few mills which do not employ steam turbines somewhere throughout the plant. It may be only a small unit driving a blower in a gas producer plant, or a larger unit geared to a blower for a blast furnace, or a still larger unit direct connected to an alternator for the generation of electric energy. Regardless of the size of the unit, certain fundamental problems are common to all. The oil is subject to rapid circulation, severe churning, sudden relieving of pressure causing atomization, aeration through spraying, and the influence of impurities such as metallic dust, room dirt, and water.

We have in mind the case of a 6000 Kilowatt Turbo Alternator in which a good grade of turbine oil had been in use for many years. The unit had wrecked itself, with particular damage to the exciter and the bearings. This turbine had large oil sumps in the bed plate and a reasonably large tank under the No. 1 bearing. An examination of these points, after the oil had been withdrawn, showed deep sludge. The oil piping was removed and thoroughly cleaned and all sludge was removed from the oil reservoirs. Precautions were taken to scrape the sides and bottoms of these reservoirs to be sure that all hard sludge had been removed. So far as could be determined, this scraping uncovered the virgin metal of all surfaces contracted by the oil. In addition to this, all low points in the reservoirs were drilled and tapped for 1″ pipes, which were led to the basement and tied to a sump tank approximately 30 gallons capacity.

Prior to starting the unit after repairing a new batch of turbine oil was circulated by means of an auxiliary pump. The oil became cloudy immediately and a centrifuge separator was then employed to clean up same. The quantity of impurities picked up by this new oil from an apparently clean system was sufficient to clog the separator four times in 24 hours. The new oil was circulated in this manner without running the turbine for a period of three days, and in that time the separator was cleaned seven times. The oil was then withdrawn from the turbine so that an examination of the reservoirs could be made. This examination showed large pieces of hard sludge cracking away from the reservoir sides. These could be removed with a putty knife and had the texture of dry tar paper. The reservoir sides were again scraped, and this time the scraping actually reached the metal. A complete new batch of oil was placed in service and the auxiliary pump again used to circulate the oil for a period of 10 hours, with the separator in service to remove impurities. This time the oil did not pick up the same quantity of impurities, and it was deemed safe to start the turbine. However, the separator was kept in service for a period of several weeks, and continued to pick up considerable impurities. At the end of that time the tank was thoroughly cleaned and there was no evidence of sludge in any form in the reservoirs. Meanwhile, the water, which had entered the system either through the packing glands or by condensation, had dropped through the 1″ pipes to the sump in the basement and was removed manually several times a day. It was found that this water amounted to approximately a quart per 24 hours.

The moral of the foregoing story is that a batch of new oil is a dangerous thing unless properly handled.

A complete batch of used oil would not have picked up the impurities. These impurities are water-soluble and not oil-soluble. If they had been oil-soluble impurities, they would not have deposited on the sides of the reservoirs. Since new oil is hygroscopic (hungry for moisture), it immediately grabs these water-soluble impurities and carries them along in circulation. This causes a breakdown of the oil film and it is not uncommon to have bearing failure with a new batch of oil. Due to the characteristic of being hygroscopic, new oil also has a tendency to froth. This frothing occurs due to the fact that the oil grabs air which contains moisture. This foaming will decrease as the oil becomes satiated with moisture. However, the presence of this moisture in the oil film is not a desirable feature. In the thin oil film beneath the bearing this moisture and the air explode, causing tiny ruptures in the oil film and helping to oxidize and blacken the oil. Oil which is foaming discolors much more quickly than oil which is free from foaming.

Foaming also occurs due to aeration. In this same turbine there was a drop from the return oil pipe to the level in the bed plate reservoirs of only two or three inches, yet the flow of oil was sufficient to cause considerable foaming in these chambers. A piece of ordinary galvanized roof troughing was used to lead this oil forward and lower it gently to the oil level in the bed plate chambers. In addition to this, the oil in the reservoir was then diverted by a flat baffle plate placed at an angle of approximately 40 degrees so that it had to pass over and under this plate before it could flow to the next reservoir. This arrangement also helped to drop out any water in the oil due to condensation or otherwise. In similar manner the discharge from the relief valves was spread on the baffles and lowered gently to the tank oil level. In this manner the amount of froth on the top of the oil was reduced from about 7″ to about ½″. This turbine has had a single batch of oil in service continuously for 4 years with a total make-up averaging less than 5% per year. The neutralization number or acidity number has climbed to above 1, but this is probably due to the fact that the batch has not been properly sweetened by the addition of quantities of new oil from time to time. Normal operation of the turbine demands approximately 10% new oil per year to keep a batch properly sweet.

Due to the relatively low operating temperatures of most turbines, and the high peripheral speed of the shaft, coupled with the wedge forming ability of the bearings, most large turbines use a light turbine oil. In the case of small auxiliary units where the bearings are subject to considerable conducted heat, the temperature may exceed 200°F, and has been known to reach 240 or 250°F. This temperature has a tendency to reduce the operating viscosity of the oil and cause rapid oxidation. Most of these units are ring oiled or have a wick device for maintaining a slow circulation and partial cleaning of the oil. For the lubrication of these auxiliary units, which are subject to carbonization with an incorrect oil, a highly filtered bright stock is desirable. To conclude the discussion on turbines, it is highly important that a turbine oil be so treated in the circulation system that it is subjected to as few disturbing elements as possible. The best oil is none too good from this standpoint. Every precaution should be taken to avoid entrapped air and moisture, and to prevent sludging, for sludging can be the cause of bearing failure or poor speed regulation.

STEAM ENGINES

On large mill engines, one of the more usual complaints is carbonization of the steam cylinder oil. In almost every case, where a good grade of oil is in service, this can be traced back to over-feeding. One case of a full Corliss tandem compound engine driving a plate mill had a high grade cylinder oil in service for several years at which time a carbonization deposit was indicated on the inlet valve. Analysis of the cylinder oil showed that there was no change which a laboratory test could indicate. Analysis of the steam condensate showed no impurities, and the card on the engine showed an unbalanced load condition on the low pressure cylinder. The maximum carbonization on the high pressure cylinder was on the high pressure inlet valve corresponding to the light loaded end of the low pressure unit. The primary reason for carbonization on this unit was over-feeding of cylinder oil, and the reason that one end of the high pressure cylinder obtained more carbon than the other was because of two things. There was a natural tendency for the high pressure end to balance the failure of the low pressure end, and this led to an additional flow of steam towards the one end of the high pressure cylinder. On top of that there was a natural baffling action in the shut-off valve which had a tendency to throw most of the oil toward the one valve. This baffling action of the shut-off valve is quite common to a number of large Corliss units and can only be corrected by direct application through oil atomizers inserted through spools in the top of the valve chest and directly ahead of the valve. With oil applied at two points along the face of the valve in this manner, the steam, which is drawn from the valve chest, has some slight tendency to atomize the oil and distribute it across the face of the valve and over the cylinder walls. Of course, there are some cases where carbonization of cylinder oil takes place due to an improper oil having been chosen. But, today, there are any number of quality oils, highly filtered and properly compounded to withstand the carbonizing influence of super-heated steam. Care should always be taken, however, not to over-feed cylinder oils. There is a correct feed and this should be maintained.

AIR OPERATED TOOLS

There are a large number of operations throughout the average steel plant which employ air to actuate a piston or a rotor. In general, the lubrication of air operated equipment is sketchy, to say the least. In some cases a bit of graphited grease is used, in others a lime soap grease will be used to coat the operating parts when they are removed for cleaning, and then oil is used for operating, applied by hand occasionally. The failure to lubricate these air operated tools gives rise to a large loss in power and a considerable wear.

If each and every air operated tool were equipped with an air line oiler, and the proper oil for the tool applied in this manner, the power requirements for air would be reduced probably 25 to 50% and the operation of the tool itself would be improved very noticeably. Production would be increased and the effectiveness of the tool in general would be much greater. We have in mind a turn-over table where the air operation consisted of a pilot valve and a main valve, the main valve equipped with leathers. With incorrect lubrication, these leathers needed frequent replacement. With correct lubrication, the life of the leathers was greatly increased, the operation of the unit was more positive, and the power requirements decreased. Every piece of air operated equipment should be equipped with air line oilers. These oilers function only when air is passing through the line. The correct type of air line oiler can be adjusted to give a very meager feed.

PLAIN BEARINGS

In any steel plant, there are thousands of plain bearings, by which we mean bearings which are not ring-oiled and may be supplied with oil or grease by hand-application, by cup-application, by an oil circulation system or by a grease-pressure system. We have apparently made some advance in bearing design from the standpoint of better bearing metals and corrections in methods of application. However, we still throw away many of the advantages gained through better bearing metals and better methods of application, by continuing to groove these bearings in much the same manner as in the days when all bearings were grease-lubricated. A study should be made of each and every bearing application to determine the approximate area of maximum pressure during service. The grooving should then be designed to properly distribute the lubricant ahead of this pressure area. Lubrication engineers for various refiners speak of the wedge-forming ability of a shaft and bearing.

We had a recent example of improper grooving on a bearing removed from a pinion stand. This is an oil-lubricated bearing, and the area of maximum pressure was close to the joint on the leaving side. Large half-moon grooves, three in number, were gouged directly in this pressure area, probably destroying at least fifty percent. of the useful area of babbitt. This particular bearing should have had a single groove running straight across the center and tied to the chamfer on the incoming side by means of riser grooves, so that ample oil would have been sent to the central distributing groove. This groove should then have been shaded so as to toboggan the oil between the shaft and the bearing, as the shaft approached the area of maximum pressure. The wedging action of the oil is what supports the shaft. With slower speed, this wedging action is not as great, and one depends more upon film strength of the oil itself. For slow speeds, therefore, we use heavier oils, and for high speeds, as in turbine work, we use light oils.

RING-OILED BEARINGS

Ring-oiled bearings are found on electric motors, centrifugal pumps, fans, hoists, line shaftings and a wide variety of equipment. A ring-oiled bearing is really a self-contained circulation system, for the oil is constantly re-used. This oil is subject to contamination by room-dust and water. The water may come merely from condensation of the moisture in the atmosphere, or it may come, as in the case of centrifugal pumps, by direct leakage along the shaft.

One of the most common faults in the lubrication of ring-oiled bearings is overfilling of the bearing. The operator usually fills the bearing while a motor is running. At this time the ring is carrying considerable oil around with it, and the level in the sight gauge has dropped. The operator proceeds to pour in sufficient oil to bring the level up to the proper standstill mark. The net result is that when the unit is shut down the oil overflows, causing a waste of oil and usually saturation of the motor winding. This gives rise to eventual short-circuiting of commutator, field-pole windings and a generally unsightly condition around the floor. This condition can be readily overcome by the use of constant level oilers, which are nothing more than an inverted bottle such as would be used for feeding chickens. As the level drops below a predetermined minimum, air is allowed into the bottle and the oil drops down. No oil is added except to the bottle, and in this manner the bearing is protected against ever being overfilled.

In the case of many bearings which are subject to a leakage of water, or in the case of fan bearings which are subject to extreme condensation, this water gives rise to the formation of sludge. The water can be and is being readily removed by the use of goosenecks, whereby an oil head plus a water head on the bearing side is balanced against a water head externally in such a manner as to automatically remove any water which may enter the bearing.

HEAVY DUTY BEARINGS

The large heavy duty bearings such as are used in our continuous mills of the older type are a very rough and ready sort of bearing. We are not too careful about the condition of the roll necks, nor are we very careful about the way in which the bearing itself is finished. Not too much attention is paid to the type of babbitt used, nor the position in which our brass wearing plates are situated. Every one has a different idea as to where these brass plates should be. Fundamentally, we are attempting to get the equivalent of a flat piece of brass directly in the pressure area. Inasmuch as our pressure area may vary somewhat, we therefore place in diagonal strips of brass to approximate the position of the straight piece of brass as nearly as possible. Just what the action of the brass is remains a matter of conjecture. Possibly it has some action equivalent to the formation of the oil wedge in providing a soft area for a grease wedge to form just prior to the moment the shaft reaches the brass. Were it not for such an area being available, the grease would have little or no opportunity to be laid on the roll necks.

The edges of such bearings become very sharp with use and are a beautiful wiping edge. Furthermore, it is quite essential that they remain a wiping edge so as to remove scale, which has a tendency to enter the bearing clearances and act as an abrasive.

Bearings on hot continuous mills and on continuous strip mills of the old type are always subject to a flood of water. The condition of this water varies in temperature, acidity, alkalinity, and the amount of impurities which the water carries. Where these bearings are grease lubricated, as is usually the case, the grease is called upon to adhere in the presence of this water. Grease manufacturers have done considerable experimental work and have changed their greases from time to time to meet this condition.

SHEET AND TIN MILL BEARINGS

In the category of heavy duty plain bearings come the bearings of sheet and tin mills of the old type 2-high mill. The lubrication practice on these mills has always been to take the returns from the pits, place them in a boiler or kettle together with some new grease and a mixing grease, and boil them to remove the scale; bring them up to a final temperature of about 525 degrees, then draw off to a pit, cut the grease up into blocks, and stack the blocks to age. While the subject of grease has always been a moot point on which no two operators agreed, very little has been done from the scientific standpoint to standardize on the resultant product secured in grease blocks. Work along these lines has developed some interesting points.

For one thing, it has been found that a close check of temperature during the boiling period is essential. A graphic thermometer provides the most satisfactory check and gives a quick indication of failure to stir the grease. Proper attention to the design of the kettle with regard to heat transfer is essential, so that there will be no hot spots where grease would have a tendency to char. Gas fired kettles are better than coal fired kettles, from a standpoint of temperature control during the cooking of the grease. Records should be kept of each and every batch of grease as to the amount of returns, the amount of new grease and the amount of mixing grease used. It is a simple matter to check the melting point of a grease, and it is interesting to know that the melting point of a grease sample removed from the kettle just prior to drawing the grease is exactly the same as the melting point of the same grease which has been made into blocks and allowed to age for a month or more. Recent work in connection with hot neck greases indicates that there is no change in the lubricating ability of the grease due to aging.

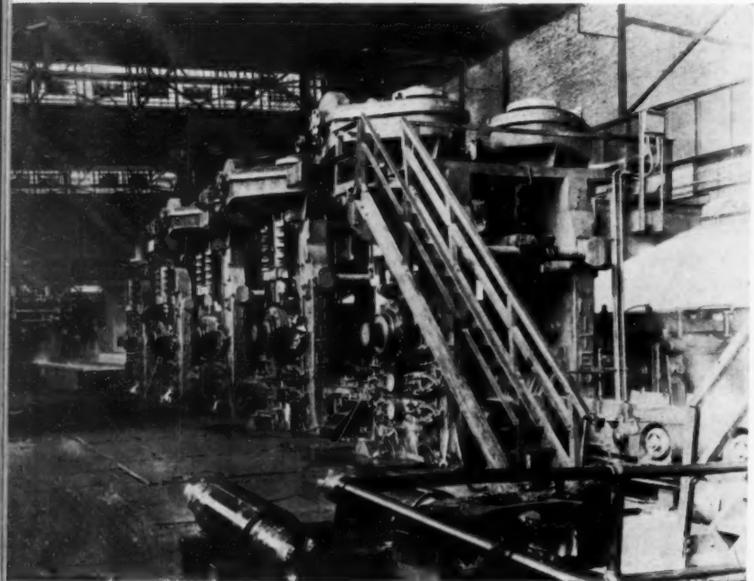
Foreign mills do not make grease blocks but run their hot neck grease direct from the kettle to a grease buggy, which delivers it to the mills.

One of the troubles which is prevalent with hot neck grease is splashing to the sheets. This can be reduced through better control of the grease and the manufacture of a product which has greater stringiness in itself. However, another cause of splashing where the grease is chunked is the use of large blocks. If trouble is being had with splashing, it is well to cut the grease into smaller blocks.

In the case of swabbing, the only control is to maintain proper grease texture and melting point. The exact temperature of the bearings and the roll necks on these mills is hard to determine, due to the presence of water in actual operation. Any attempt to take a reading by means of a thermocouple is thwarted by the presence of the water. Readings taken immediately after shutdown indicates normal running temperatures between 200 and 250°F, where the roll itself may be operating 650 to 700°F on the surface at the center.

The melting point of a grease should be, of course, adapted to the type of application. For use in grease pots, a grease should have a melting point certainly not over 212 degrees, as most of the steam which would reach the pot is at practically that temperature. For gas fired pots the melting point can be higher.

5 Stand—4 High Finishing Train of 54″ Hot Strip Mill.



ANTI-FRICTION BEARINGS

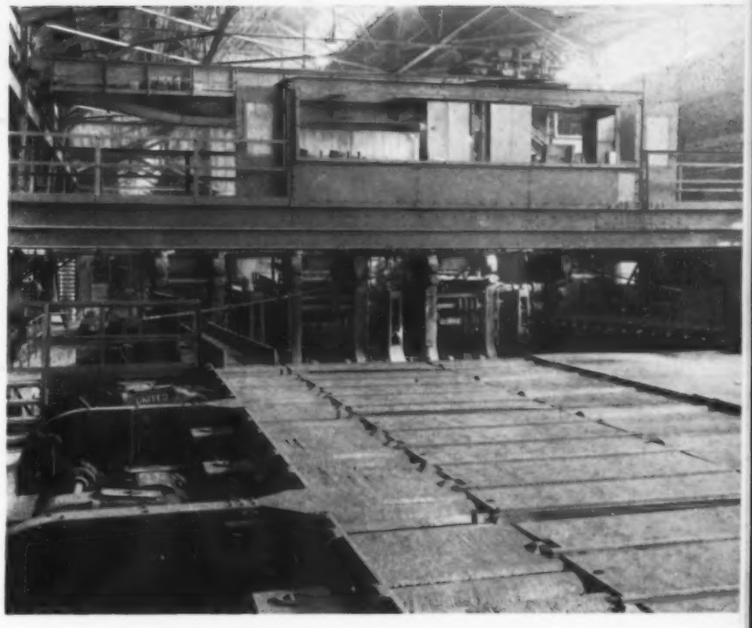
The anti-friction bearing is increasing in service every day. We are all familiar with the application of the roller bearing to our new tandem mills and in the gear sets of the drives. We have discussed the various problems in connection with this type of bearing in preceding papers. These problems are limited to a few men, but there is a major problem in connection with anti-friction bearings which is met by numerous electricians and maintenance men in every plant.

The anti-friction bearing, from the very nature of it, must roll to be effective. If we place anything in the path of this rolling which has a tendency to slow down the roller and cause it to slide, we reduce the efficiency of the bearing and cause heat to be generated. It is not an unusual circumstance to burn out an anti-friction bearing, whether it be a roller bearing or a ball bearing, by over-filling the bearing with lubricant; this is just as true of oil as it is of grease. Where oil is used, it pays to determine the practical minimum level at which the oil can be held and the bearing still lubricated well. When this has been determined, a constant level oiler, such as we have already discussed, can be adapted to the bearing so as to assure oil at this min-

imum level. High speed pumps, fans, and other equipment which operates at high speed, using anti-friction bearings, will generally be lubricated better with oil than with grease; and the temperature can be kept low if the oil level is maintained at the minimum so that the bearing merely dips. Manufacturers of anti-friction bearings recommend a very small dip, in many cases less than ¼".

Where grease is used in anti-friction bearings, this grease, in general, should be a soda-soap product. Soda-soap greases are what are known as fibre greases normally, due to the fibrous appearance of the grease. A roller bearing can use a fibre grease satisfactorily because the fibres are rolled around the bearing. However, a ball bearing will not satisfactorily operate with a fibre grease, and the soda-soap grease in this case must be of a smoother texture, similar to lime-soap greases. Otherwise, the ball bearings will channel. As has been previously stated, care should always be taken not to overfill these bearings with grease.

If an anti-friction bearing operates under a condition where water leakage into the bearing is possible, then a soda-soap grease cannot be used because such a grease easily saponifies. In the case where water can get into the bearing, it is necessary to use a lime-soap grease, because such greases are (so-ealled) water-proof.



28" 3-High, 3 Stand Finishing Rail and Structural Mill.

AIR COMPRESSORS

While we are on the subject of bearings, it is well to mention bearings which are lubricated by splash systems and subject to shock loads, such as the bearings of air compressors, small steam engines, etc. One of the outstanding causes of failure of such bearings is the sludging of the oil in the splash system. This sludging occurs due to overfilling of the crank case, which causes a heavy dip of the crank pin bearing and connecting rod. If there is any water present, the heat generated by this dipping action, together with the constant churning of the oil, causes the oil to whip up into an emulsion, which if not broken up in a settling tank placed externally soon develops into a permanent emulsion. The openings to the bearings become clogged, with a subsequent failure of oil supply and the loss of the bearing. It is therefore essential that the level of the oil in a splash system should be maintained at the lowest practical point.

There is another reason for maintaining this level low, and that is to cut down on the amount of oil sent forward to the piston rods. This is of importance whether it is on an air compressor or a steam engine. In the case of the steam engine, the engine oil has a tendency to thin down the film of cylinder oil and cause trouble with the packing. In the case of an air compressor, the crank case oil is sent forward to the cylinders, sometimes in quantities sufficient to cause carbonization, even though the same oil is used in the crank case as in the cylinders. It is a well known fact that air compressors should receive as small a quantity of oil as possible. Air compressor feeds to the cylinders are almost always too high and a reduction in the amount of oil sent to the cylinders usually reduces the amount of carbon formation on the valves.

CIRCULATION SYSTEMS

We have already discussed under the subject heading of Turbines the importance of correct design of circulation systems. We know of several rather costly experiences which have resulted from failure to properly lay out and maintain circulation systems for oil supplied to large gear sets. In one case, of a circulation system for a tandem cold mill, one roll stand was removed. The piping, being underground and inaccessible, was not removed but merely plugged. Some time later, the oil in the filtering system showed to be strongly emulsified, and the bearings on the gear sets began to run so hot that it was necessary to add new oil to the bearings and keep a flow of compressed air on them to operate. A laboratory analysis of the oil showed the equivalent of nearly 25 pounds of raw sulphuric acid in the system. An investigation showed that one of the abandoned lines had become corroded to such an extent that the pipe was eaten entirely through, and acid and water which were leaking through the foundation from an adjacent pickling department were getting into the system. It was necessary to drain the entire system and replace with new oil. This caused a considerable loss in production, together with a large labor charge.

It is not necessary to have acid in the form of sulphuric or nitric acid present in oil in order to experience emulsification. When the water content in an oil becomes as high as 5 to 7%, the rapid circulation, coupled with the heat generated in the bearings and gear sets, together with the extremely rapid and violent churning to which the oil is subjected, causes emulsification to occur. Where large quantities of water can get into the system, as is often the case in hot strip mills, it is absolutely essential that the filtering system be ade-

quate to remove this water rapidly. In the case of heavy bodied oils, it is often necessary to have special adaptations made by the filter designers in order to handle these oils. Refiners today are making heavy bodied oils with much improved demulsification characteristics. Some of the heavy bodied oils available today for gear lubrication and heavy bearing lubrication have demulsifications at 130°F which are as good as used to be quoted at 180°F.

The same precautions which should be taken with turbine oil are essential when it comes to large systems for heavier bodied oils. Water should be removed automatically as near as possible, there should be no sudden drops which will cause aeration of the oil, the lines should be as accessible as possible and not run through concrete foundations unless they are left free for easy removal. We know of a case where leakage of 2 barrels of oil per day took place directly under the foundation of a large drawing mill engine, and it was impossible to reach this point. Circulating pumps which handle the oil should be of ample capacity, and normally there should be a duplicate set so as to avoid any possibility of a shutdown due to failure to circulate oil. Periodic laboratory analyses of the oil in the system are advisable, particularly where the amount of make-up added is small. Almost every mill in operation today is overloaded. Pinion stands are doing double duty, and the oil film on the gear teeth is called upon to function under conditions for which the equipment was not originally designed. It is therefore essential that every precaution be taken to maintain this very important lubricating film in the best possible condition.

AUTOMATIC GREASE SYSTEMS

With the installation of automatic grease systems on roll neck bearings, it is the usual practice to install rubber hose between the pipe lines and the bearing, due to the necessary adjustment of the bearing when changing roll diameters. Ordinarily these hose do not require a great amount of attention, but on one occasion it developed that a bearing ran hot and a complete inspection of the entire feed line was made to find the source of the leakage, but none was found. The piping was then dismantled and no obstruction was found in the metal pipe. However, upon trying to run a wire through the rubber hose, it could not be done. The hose was then cut in two and found to be completely closed. The hose being made in two layers, it separated and expanded; thereby closing the hole. Periodic inspection of rubber hose is advisable, both inside and outside as far as possible.

Temperature warning devices are desirable in connection with costly bearings. These should be set so that upon reaching a pre-determined temperature, they will warn the operators. Another point which should be watched in connection with automatic grease systems is the condition of the pilot valves which regulate the feeds to the various bearings. Any abrasive material which enters the grease system causes wear of these parts and eventual loss of pressure, or, occasionally, a continuous pressure and excessive feed.

All piping in connection with grease systems should be run in such a manner as to be protected from all work which is done on the roll stands during periods when rolls are being changed. All connections should be permanent, so far as is possible. Where grease is removed directly from a barrel to the pressure system by means of a barrel pump, care should be taken when inter-changing from one barrel to another not to let the pump rest on the ground nor pick up dirt in any manner. It is well, if possible, to have the barrel pump outfit in a totally enclosed room, as free from dust as possible.

Wear on the diameters of mill roll necks on which roller bearings are mounted have been a source of more or less trouble due to foreign matter getting between the inner race of the roller bearing and the neck and also the fact that on certain applications a lubricant could not be provided that would stay put for a period of one to four weeks which would be required between roll changes. We have one case in mind where the necks of the rolls began wearing a short time after being put into operation due to the slight rotating movement of the inner race of the neck. All recommended types of grease were used, but none of these would stay put for even a week's time. This condition became so serious that tapered necks and races were suggested as this type of mounting had been used to eliminate movement. This procedure would have been quite costly; however, one point was agreed upon and that was if the neck were kept properly lubricated, wear would undoubtedly cease. Steps were then taken to provide a method of applying the lubricant which consisted of drilling a ¼" diameter hole from the outside ends of each end of the roll necks to the center line of the bearing, and then a ¼" diameter hole at right angles to the first hole through the neck. This provided two outlets for the lubricant, which as applied by hand operated grease guns every four hours. This application entirely eliminated the wear and lubricant was on the necks when dismantled, regardless of the length of time in the mills. An automatic arrangement of applying the lubricant at predetermined intervals can also be used instead of the manual operation.

HYDRAULIC OIL SYSTEMS

Where a number of units in close proximity and at infrequent intervals are to be power operated central hydraulic oil systems are quite inexpensive to install compared to individual electric drives.

In installations of this character it is important to procure the correct grade of oil and also to properly handle same. Where the oil pump runs continuously a by-pass valve is required to prevent the pressure from building up beyond the designed point of the equipment. The pump should be designed so that the minimum amount of oil is by-passed to prevent excessive heating of the oil.

The oil handling system should consist of a reservoir of sufficient capacity to cool the oil. The overflow and return pipes should be run to within a few inches of the bottom of the reservoir to prevent foaming of the oil which if permitted causes severe vibration of

the pump. Two compartments should be provided in the reservoir to eliminate churning of the oil going into the supply line. All pipes should be thoroughly cleaned to protect valves and pumps. We have seen considerably difficulties when the above simple precautions were not observed.

We would welcome the discussion of some of the experiences that you men have had as in that way a case may be brought to someone's attention which will help correct a similar condition.

DISCUSSION

PRESENTED BY

F. L. GRAY, Lubrication Engineer, Carnegie-Illinois Steel Corp., Gary Works, Gary, Ind.

F. J. THOMAS, Lubrication Engineer, Republic Steel Corp., Cleveland, Ohio.

A. F. BREWER, Technical Division, The Texas Company, New York, N. Y.

H. R. GILCHRIST, Lubrication Engineer, Carnegie-Illinois Corp., Youngstown, Ohio.

S. A. NEWMAN, Assistant Division Manager, Gulf Oil Corporation, Pittsburgh Sales Division, Pittsburgh, Pa.

F. L. Gray: Mr. Klein's paper is a frank discussion of steel mill lubricating problems. His methods of applying corrective measures may differ in some respects to the ideas of others, but it is satisfactory results that assist in the maintenance of our equipment. This paper emphasizes the fact that the lubrication of steel mill equipment follows no fast rules and only by frank discussions with our associates in the industry can we hope to advance the art of lubrication.

Mr. Klein mentions a turbine oil that increased in acidity to 1.0 mg KOH per gram of oil over a four-year period. He suggests that the high acidity might be due to the small percentage of make up oil used.

It is our experience that make up oil is contaminated by oil in service to a greater degree than the oil in service is helped by the addition of new oil. Oil in a 15,000 K. W. Generator increased in acidity to 0.86 mg KOH per gram of oil over a period of eighteen months. This oil was removed, the system cleaned, and a different oil of better design for this class of work was used. After eight years usage with normal additions our analysis of this oil shows only 0.04 to 0.06 mg KOH per gram of oil.

Again may I express my appreciation of Mr. Klein's paper.

F. J. Thomas: Mr. Klein's paper has covered a number of lubricating problems frequently encountered in steel mills.

The tendency to over-feed cylinder and compressor oils must be kept in check. This is as important for proper operation of equipment, as for economy in use of lubricants.

Reliable tests prove that Mr. Klein's statements as to the advantages of using air line oilers for air operated machinery are fully justified.

It is true that even now too little attention is being given to the proper grooving of plain bearings. The load surfaces should never be broken by complicated grooving.

I am glad to see the use of constant level oilers for ring-oiled bearings advocated in this paper. These can be very helpful in obtaining cleanliness and reliable lubrication at many points.

Referring to the subject of circulation systems, there is not yet enough being done by the manufacturers of mill drives to insure that the oil furnished gears and bearings will not be lost in large quantities.

A large amount of leakage from gear cases and pinions may be observed even in some of the latest wide strip mills installed. Bearings and casings should be designed to eliminate this leakage which becomes objectionable and even dangerous in the mill.

I wish to say that Mr. Klein's paper was a very interesting and enjoyable one, and shows that engineering departments can be keenly aware of problems confronting maintenance and operating men.

A. F. Brewer: C. J. Klein's paper on "Lubrication of Steel Mill Equipment" is, in my opinion, one of the outstanding contributions to the literature on this important topic which has been made during recent years. It has been most interesting to note the practical way in which he has demonstrated certain of his points by reference to actual operating conditions. There are, consequently, but a few points upon which I can comment.

One in particular relates to his discussion of the steam turbine condition wherein new oil, after being circulated for a period of but a few days, tended to take up a considerable volume of foreign matter from within the system. This confirms experience with other types of units, notably Diesel engines and heavy duty automotive engines. It has been observed to be most prone to occur where the new oil has been manufactured from an entirely different type of crude than the oil which has been used. Under such conditions the initial charge of oil should be regarded as a solvent or flushing oil, just as we regard our flushing oil in automotive service. Subsequent replacement by a fresh charge of oil should then give satisfactory performance, as has been brought out by Mr. Klein. Unfortunately, however, flushing of the lubricating system in a steam turbine of comparatively large size may become a rather expensive matter, especially if consideration is given to the use of a turbine grade of oil for this purpose. It would be better where practical to use a considerably lighter grade of oil, circulating same by means of the auxiliary pump, as referred to by Mr. Klein. During this procedure the oil would be performing minimum duty as a lubricant and maximum duty as a cleansing agent for the system.

(Please turn to page 39)

Resistance Welding IN STEEL MILLS

By WALTER ANDERSON, Vice President
and MALCOMB CLARK, Gen. Manager
Taylor Winfield Corporation
WARREN, OHIO

Presented before the Annual Convention of the A. I. & S. E., Detroit, Michigan, Sept. 22-25, 1936

▲ THERE is every evidence that the future holds out the possibility of many new developments in resistance welding equipment which will undoubtedly carry with it the increased use of steel. This will be the natural process of development since the average individual does not have to look very hard to find many miscellaneous articles, now made of other material, which would be considerably improved and undoubtedly made to sell at a lower price if a satisfactory method of fabrication could be found. It is our sincere belief that the answer to many of these problems will be found in the use of resistance welding machinery.

One very recent example of this is the change from glass radio tubes, which were really an outgrowth of the incandescent lamp, to the steel radio tubes. Although the advantages of steel for the small receiving tubes, such as one uses in the home, may not be obvious, they do exist; and in the case of large power tubes and other high vacuum electronic equipment there are many worthwhile advantages in the use of steel rather than glass. The use of glass necessitates a special development of glass working machinery and, at best, results in a bulky structure. By using steel much greater power can be handled by electronic devices of comparatively small dimensions and in manufacturing, the experience of the steel working industries can be readily drawn upon. The primary factor in making this change possible has been the use of resistance welding machinery for fabrication.

In the line of transportation, everyone is, of course, familiar with the vast steps that have been taken in the past few years to eliminate the wood in automobiles and to produce an all steel structure. Here, again, resistance welding machinery has played a very important part. Perhaps we should not go so far as to say it would have been impossible without this machinery, but it is very probable that it would not have been economical. In the same way, while the change from wooden railway cars to steel is not new, there have been radical changes made in the design of the steel cars resulting in the new light weight high speed streamlined trains. The old method of using heavy steel plate and riveted joints has been replaced by the use of light gauge stainless steel fabricated by resistance welding. For the most part the resistance welding machinery in this case is in the form of what we call gun welders. Gun welders today are as common in many plants as the hammer and chisel were in the wood working plants of several generations ago. This progress in the line of transportation cannot be looked upon without some speculation as to how our houses of the future may be built. There is already a very definite trend toward the use of steel for the fabrication of dwellings. When this comes to pass, as it undoubtedly will sometime in the future, resistance welding will again play a large part in making this progress possible. It is quite likely that the tool box of the present day carpenter, which consists entirely of wood working

WALTER ANDERSON

MALCOMB CLARK

equipment, may be replaced to a large extent by various types of welders and metal working equipment; so that when you have your house repaired, instead of the repairman nailing in a new wooden panel, he may weld in a new steel one.

It does not take a great deal of imagination to see the great possibilities of the use of steel as a material and welding as a means of fabrication for future developments.

PART TWO

BY MALCOMB CLARK

In practically all modern industrial expansion there is a definite trend toward the use of continuous processing. This, of course, offers many advantages in the way of reduced labor costs due to a minimum of handling, and high production which can be reached due to complete machine operation. Continuous processing has, of course, been used in steel mills for many years but there is now a definite trend toward increasing the degree of continuity in order to gain some of the aforementioned advantages.

At the present time continuous processing is found in the hot mill, in the pickling vats, in the cold strip mills, in cleaning operations and other similar processes. However, in most cases each of these operations is handled as a separate unit and the stock is transported from one to another in the form of relatively small coils, the size of the coils being limited in general by the weight of the billets that can be handled. When these rolls are brought from the hot strip mill, it is next necessary to run them through the pickling vats and since these vats are of great length it is absolutely essential that a continuous flow of material be maintained through them. There are two general methods now made use of to join the stock together. One of these is known as stitching and it is purely a mechanical bond. When this type of bonding is used it serves merely to hold the two ends of the strip together while passing through the pickling solution and it is necessary to cut the stitch out at the other end, consequently there is no increase in the length of coils obtained.

The other method is welding. There are several types of welding which may be used for this purpose. In selecting the type of welding equipment to be used there are several important factors which should be taken into account. The width and gauge of the stock determine the ease with which it may be handled and are therefore important considerations. Stock which is clean may be spot welded very satisfactorily whereas stock carrying heavy scale, such as that resulting from a hot strip mill, is very difficult to spot weld; and, in this case, flash welding should be used. Another important consideration is the tension to which the stock is subjected in processing. Of course, if this is very light, a small number of spot welds may be used; whereas if the tension is high, it is essential that a large number of good spot welds be used or flash welding resorted to. Then, of course, it is necessary to give careful consideration to the problem of whether or not it would be advantageous to increase the size of the coils as well as provide a means of maintaining the continuity of the immediate process.

In the case of light gauge narrow strips, when the joining is merely for the purpose of maintaining a continuous flow of material and no particular advantage is to be gained from increasing the size of the coils, spot welding may be used advantageously. In this case a small foot-operated welder is usually sufficient, it being so located that the operator may manually gather up the two ends to be welded and carry them to the welding jaws and make the necessary joints. This is particularly true where the stock is relatively free from scale and where there is not a high tension on the stock during processing. If, however, there is a heavy scale on the stock such as is found on coils taken from the hot strip mill, it is rather difficult to make satisfactory spot welds. In this case, flash welding is entirely satisfactory; the scale has little or no effect on the quality of the weld and hence is not a factor. In case flash welding is used, some consideration should be given to the question of whether or not it is desirable to remove the flash. If it is only necessary to maintain continuity of flow through the immediate process and the processing is of such a nature that no damage can be done by the burr, it is not necessary to remove the flash. If on the other hand, however, the stock is to pass through polished rolls, such as in the cold roll mill, it is absolutely necessary that some form of flash trimming be used, in order to avoid scarring of the rolls. Also, if it is desirable to obtain larger coils for subsequent operations, flash trimming should be used, in order that there be no burrs on the stock.

In the case of stock of great width it is, of course, impossible to use manually operated spot welders. In this case the hydromatic type of welder is found to be very satisfactory. This machine consists of a row of electrodes, which are driven in sequence by a hydraulic system, resulting in a row of spot welds across the stock. Here again this weld serves mainly to maintain a continuity of flow in processes where overlap can be tolerated and, as in the case of narrow stock, may be replaced by flash welding and very definitely should be replaced by flash welding if the stock is covered with any appreciable amount of scale or a smooth weld is essential. In the case of wide rolls of comparatively heavy gauge, the problem becomes more definite. In modern high speed rolling mills, the dimensions of the rolls are governed to a certain extent by their temperature. A suitable temperature gradient throughout the roll is obtained by heating in some places and cooling in others. Any such process as this, of course, requires a certain length of time to reach equilibrium. If the operation is such that it is frequently interrupted, it is next to impossible to maintain the desired conditions at all times. Another important factor is the speed of the rolls. When a mill is threaded an appreciable time is required to accelerate to the full speed. While this process of acceleration is going on there is an unavoidable amount of non-uniformity, which is decidedly undesirable.

The perfect method of operating a cold strip mill would be to have some means of joining the stock ahead of the mill so that one hundred percent continuous flow of material could be maintained. In this manner, after the first half hour or so a very high degree of uniformity would be reached and it would be possible to

maintain this condition as long as the mill is kept running. It is our belief that the use of resistance welding would make it possible to attain this condition. At the present moment several mills have taken some of the first steps in this direction.

The first step is to install suitable butt flash welding and trimming equipment ahead of the pickling process. This apparatus usually consists of a hydraulically operated welder followed by a flash trimmer and hydraulic transfer. The coils are brought from the hot strip mill and are threaded through suitable rolls to feed them to the welder. Beyond the welding operation a suitable looping pit is provided to take up the slack, which must be drawn from by the pickling process while the weld is being made. This pit should be large enough to accommodate the equivalent of about three minutes flow of material. The operator of the welder has all the controls governing the threading rolls feeding the welder, the hydraulic transfer and the flash trimmer, so that by these means he brings the stock into the welder, makes the weld, transfers it to the trimmer, removes the flash and releases it to continue on through the pickling vat in approximately three minutes. A detailed description of the equipment used will be given in the last part of this paper. This weld after trimming is of such quality that it need not be cut out. It very definitely results in coils of any size the manufacturer may care to handle at the output of the pickling process. In one installation for example, five four-thousand pound coils are joined together to make a twenty thousand pound coil, which is taken to the cold strip mill. When this twenty thousand pound coil is threaded into the cold strip mill, all the advantages of continuity of operation, which were described above, are obtained to a high degree.

The next step is, of course, to install a similar welder and a looping pit just ahead of the cold strip mill; then, in a manner similar to that by which continuous flow is maintained through the pickling vats, a high degree of continuity could be obtained through the cold strip mill. It seems very definite that such an investment would pay for itself in increased efficiency of operation and quality of stock. It is, of course, within the realm of possibility to run the output of the pickling vats directly into the cold roll mill and eliminate the second flash welder. This, however, results in a tie up of such a large amount of machinery that a break down at any one point would close down the whole mill. It is probably better to use a second welder ahead of the cold strip mill thereby making possible the use of a buffer stock of coils between the pickling and cold rolling.

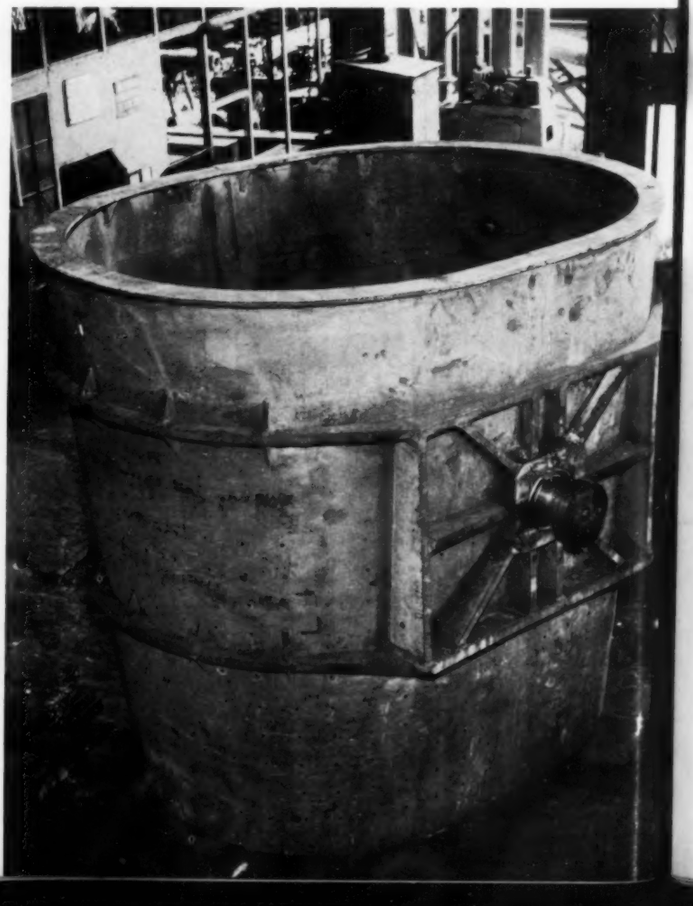
NEW LADLE ELIMINATES MUCH SURPLUS WEIGHT

A hot metal ladle of welded construction that has been designed by the Bethlehem Steel Company virtually halves dead weight in the tapping and pouring of steel. It holds 120 tons of molten metal. Yet it weighs only 31,000 pounds. The older design of ladle that it supplants weighs 55,000 pounds, yet holds but 100 tons of hot metal. The new ladle is elliptical rather than circular in its horizontal cross sections.

It was designed to meet a specific problem in several of the Bethlehem open hearth units where melts were being increased from 100 to 120 tons. To hold this increased tonnage of hot metal, it was self evident that the new ladle would have to be either taller or of greater circumference. Increasing the height of the ladle would have resulted in the disadvantage of increased hydraulic head. Therefore, by making the horizontal cross sections elliptical rather than circular it was possible to increase the capacity of the ladle without lengthening the distance between trunions. Thus the same trunion hooks can be employed that were originally designed for the smaller 100-ton ladle.

The welded ladle is so much lighter that it goes far to offset the added working loads that the greater tonnage of hot metal imposes on the handling equipment. The welded construction made possible direct attachment of the trunions to the ladle, and weight was saved throughout, due to the lighter plates that could be used without sacrifice of strength. And there was also a saving in weight in the trunions of welded reinforced shoulder construction that were substituted for cast trunions. Essential strength for the bottom construction was secured by the use of welded-in 2″ x 6″ reinforcing bars in conjunction with a flat plate rather than a flanged section, the use of which was precluded, in any case, because of the ladle's elliptical shape.

The accompanying illustration indicates the nature of the welded construction employed.



Stress Analysis
OF LOCOMOTIVE AND OTHER LARGE AXLES

By T. V. BUCKWALTER, Vice President
and O. J. HORGER, Research Engineer
TIMKEN ROLLER BEARING CO., CANTON, O.

Paper presented before the Pittsburgh District Section, A. I. & S. E., February 29, 1936

Tests discussed in this paper show that the fatigue strength of a 2″ axle with press fitted member is only ½ to ⅓ of the strength of the axle without press fit. By surface rolling the axle at the press fit portion this strength may be more than doubled. The technique of surface rolling is described. Equipment is being purchased to test 12″ axles in fatigue in order to determine the strength of various designs and materials and if similar improvement in strength may be obtained by rolling of the large sections.

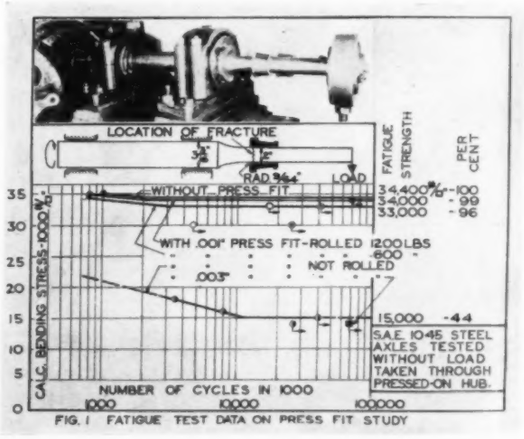


Figure 1

THE AXLE PROBLEM

The general problem of the design of axles presents two major difficulties. The first concerns itself with the forces acting on the axles under service conditions. Not knowing these forces it becomes impossible to calculate the stresses present. The second thing pertains to the fatigue strength of steel in large sections. Not knowing either the stresses present or the strength of the material in large sections the problem becomes one of good judgment and experience. It is of course necessary to maintain a factor of safety in the design which is consistent with weight and cost.

Referring to railroad axle design we find that previous experience has expressed itself by the use of empirical formula. These formulas are a result of successful performance over a long period of years with a small percentage of axle failures. In the last few years,

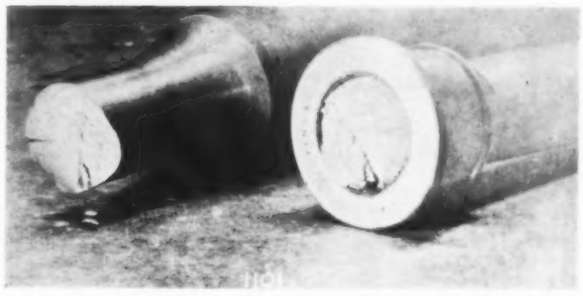
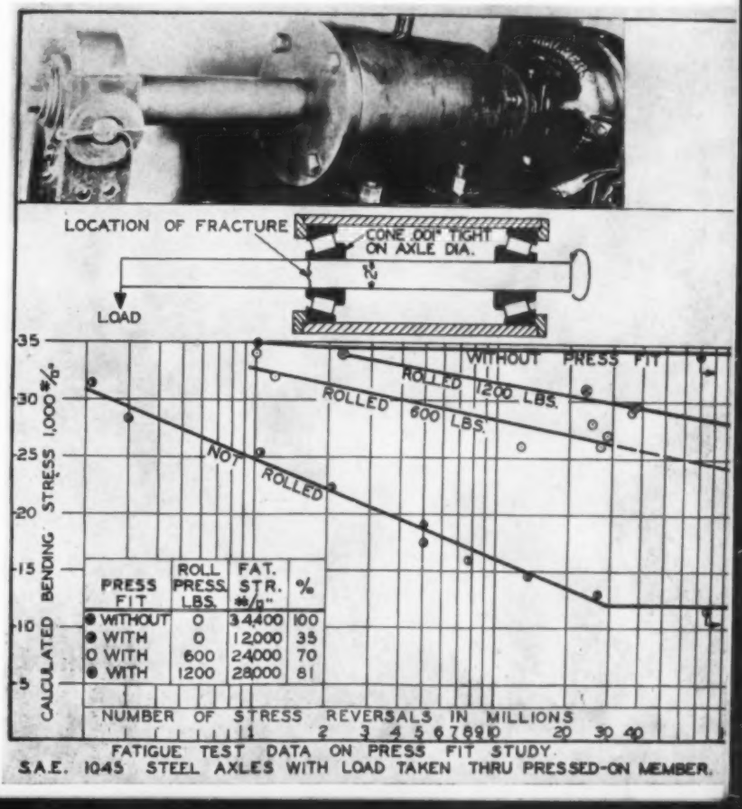


Figure 2—Normal type of fracture

however, the loads and speeds on axles have been increased. We have little knowledge of how axle stresses increase under these conditions. We do know that the application of these empirical formulas to axle designs operating under these more severe conditions result in axle failures.

The proper use of steel in large sections subjected to a reversal of stresses requires a knowledge of the

Figure 3


LOCATION OF FRACTURE
CONE .001" TIGHT ON AXLE DIA.
LOAD
WITHOUT PRESS FIT
ROLLED 1200 LBS.
ROLLED 600 LBS.
NOT ROLLED
CALCULATED BENDING STRESS 1,000 #/□"
PRESS FIT | ROLL PRESS. LBS. | FAT. STR. #/□" | %
● WITHOUT | 0 | 34400 | 100
● WITH | 0 | 12000 | 35
O WITH | 600 | 24000 | 70
● WITH | 1200 | 28000 | 81
NUMBER OF STRESS REVERSALS IN MILLIONS
1 2 3 4 5 6 7 8 9 10 20 30 40
FATIGUE TEST DATA ON PRESS FIT STUDY.
S.A.E. 1045 STEEL AXLES WITH LOAD TAKEN THRU PRESSED-ON MEMBER.

fatigue strength of an axle assembly. At the present time most fatigue tests are made on 0.3″ dia. specimens. Such data is very misleading when applied to larger diameters. It has been our experience in testing as well as that of other investigators, both in this country and abroad, that fatigue strength decreases considerably with increased diameter.

Summarizing, it would therefore appear as though the axle design problem requires a research program devoted to a study of stresses in service correlated with the fatigue testing of large sections.

STUDY OF RAILROAD AXLE FAILURES

Several years ago the Timken Roller Bearing Company started the investigation of axle failures. It was found that a large number of failures occurred where a member such as a wheel, pulley, gear, or bearing is pressed on the axle. There were also failures which were due to improper machining conditions, at fillets or heat checking of journal seats. Our analysis of failures was confined to those that occurred at the press-fit portions of the axle. On outboard axles, where the journals are outside the wheels, the failures were located within the press fit near the inside hub face. On inboard axles, where the journals are between the wheels, the failures were found within the press fit near the inside hub face of the wheel and also near the bearing seat.

STRENGTH OF AXLES WITH PRESS FITTED MEMBERS

In our paper before this society about a year ago we showed by photo-elastic analysis that the stresses in the axle near the press fit were much higher than the calculated values. As further evidence of this stress concentration it was also shown from fatigue tests on 2″ dia. axles that a press fit reduced the axle strength to a value of ½ to ⅓ of what it would be if no press fit were present. Somewhat similar results have also been obtained by other investigators[1], [2] on smaller dia. axles. Having this information, our problem then became one of removing this local source of weakness and increasing the strength of the axles at the press fitted portion by either design, material, or manufacturing processes.

Several means of obtaining this increased strength were tested such as (1) relief grooves in the end faces of the pressed-on member, (2) providing raised seats or pads on the axle at the press fitted portion, and (3) the testing of several alloy steels and heat treatments. While all these phases were not completely investigated the indications were that about 30% increased strength would be the maximum obtainable by such methods.

LARGE INCREASE IN STRENGTH OBTAINED BY SURFACE ROLLING

Not being satisfied with such a small increase in fatigue strength the study was continued and now

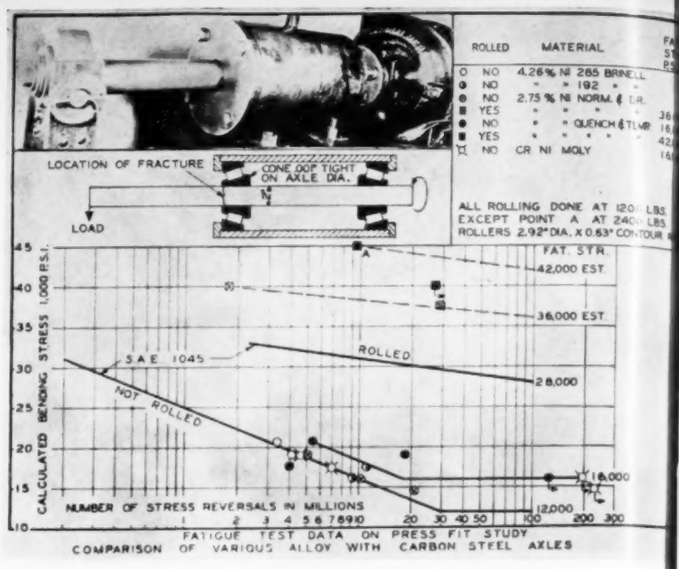


Figure 4

these 2″ dia. test axles having press fitted members have been increased 2⅓ times the strength of the conventional assembly. This large increase in fatigue strength was made possible by surface rolling (discussed later) the axle at the press fitted portion before the member was pressed on the axle. At total of three series of tests were made, the first two being on SAE 1045 steel axles and the third on various alloy steels and heat treatment.

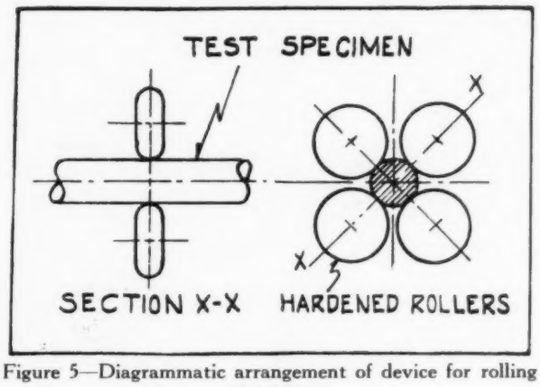


Figure 5—Diagrammatic arrangement of device for rolling the axles

DISCUSSION OF FATIGUE TESTS

First Series of Tests

Typical fatigue curves for one series of tests on press fit assemblies are shown in Fig. 1. The photograph and line diagram of the test set-up is given above the curves. In this test the inner race of the Timken bearing is pressed on the 2″ dia. test axles with a press fit of .001″ tight on diameter. It should be noted that the inner race is without rollers and does not act as a bearing, but is only pressed on the axle and rotates with the axle which is subjected to a definite bending stress. The test axle acts as a cantilever beam and is supported in the two pillow block bearings with a load applied at the end of the specimen to give the proper bending stresses in the axle where the race is pressed-on.

These curves indicate that without the press fit the 2″ axle has a fatigue strength of 34,400 p.s.i. but with

1 A. Thum and F. Wunderlich, "Einfluss von Einspann-und Kraftangriffsstellen auf die Dauerhaltbarkeit der Konstruktionen," Zeit V.D.I. Vol. 77 No. 31 Aug. 5, 1933, p. 851.

2 R. E. Peterson and A. M. Wahl, "Fatigue of Shafts at Fitted Members, With a Related Photoelastic Analysis," A.S.M.E. Journal of Applied Mechanics, March, 1935.

3 This effect is discussed in greater detail in previous paper by O. J. Horger "Effect of Surface Rolling on the Fatigue Strength of Steel". A.S.M.E. Journal of Applied Mechanics, Dec. 1935.

the press fit race .001″ tight on dia. this strength is reduced to 15,000 p.s.i. or only 44% as much. The normal type of failure obtained is shown in Fig. 2 where the fracture developed a short distance inside of the press fit.

This manner of test indicates that the greatly reduced fatigue strength results from the press fit only as the pressed-on race was not used as part of a bearing. One test was made using .003″ tight fit of race on test axle, indicated by square solid point in Fig. 1, but this assembly did not prove to be any weaker than when .001″ press fit was used.

Means of correcting this reduced axle strength are also shown in Fig. 1 where the 2″ axle seat is surface rolled at the location of the pressed-on race. This rolling operation is described later in the paper. It is sufficient to observe that by rolling the axle seat at 600 lbs. pressure that the axle fatigue strength is increased to 33,000 p.s.i. while 1,200 lbs. gives 34.000 p.s.i. Thus rolling provides 2.2 times the axle fatigue strength of the conventional press fit assembly.

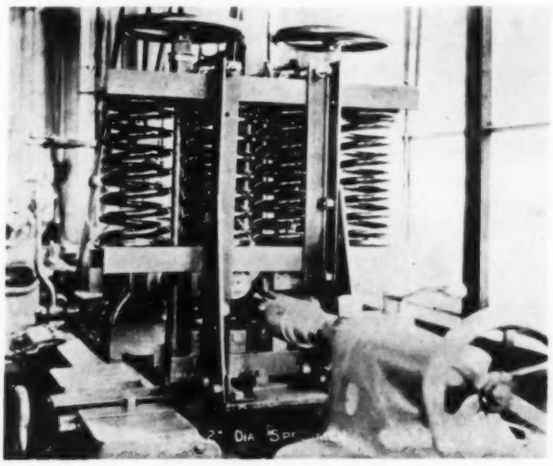


Figure 6—Method of rolling the 2″ diameter axles

Second Series of Tests

The results of another series of press fit tests on 2″ axles is shown in Fig. 3. A photograph and line diagram of the test set-up is given above the curves. Fig. 3 gives fatigue data on tests similar to those in Fig. 1, except here a bearing load is transmitted through the pressed-on race which alters the press fit pressure distribution between the race and shaft. This condition represents the case usually found in practice where the pressed-on member is a portion of a gear, pulley, or wheel with some force being transmitted through it.

These curves in Fig. 3 indicate that without the press fit the axle fatigue strength is 34,400 p.s.i. but with a member pressed on the axle .001″ tight on dia. this decreases to 12,000 p.s.i. or only 35%. The 12,000 p.s.i. obtained in the second series of tests compares with the value of 15,000 p.s.i. in the first series, the reduction of 20% being attributed to the alteration of press fit pressure due to force being taken through the pressed-on member. Again surface rolling the axle seat at the press fit portion by 600 lbs. roller pressure gives an axle fatigue strength of 24,000 p.s.i. while

SURFACE OF SPECIMEN
TRANSVERSE SECTION THROUGH SPECIMEN 100X. NOTE EFFECT OF SURFACE ROLLING.
ROLLED SURFACE SECTION 1000 X
CORE SECTION 1000 X

Figure 7—Comparison of structure of rolled axle at surface and core

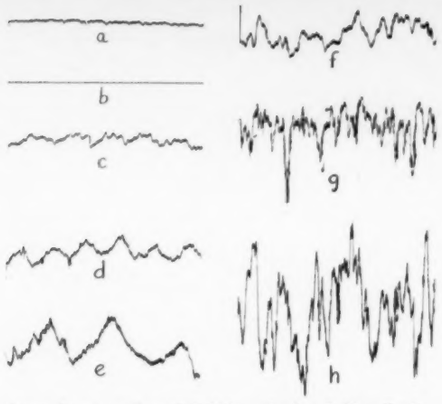
1,200 lbs. gives 28,000 p.s.i. Thus surface rolling provides an axle fatigue strength 2 to 2⅓ times that of the conventional press fit assembly.

Mention should be made of the fact that the fatigue curves in Fig. 3 for the rolled axles would indicate that the fatigue strength may continue to decrease after 100 million reversals of stress. It is believed that these curves actually become flat before 100 million reversals so that the strength would then be a little higher than the given values of 24,000 to 28,000 p.s.i. The reason for this is that using this small press fit of .001″ on 2″ dia. axle over a long period of operation at high bending stresses causes the pressed-on race to loose its fit on the axle. This was apparent from the fact that axle fracture occurring after many stress reversals developed in the region of about one half the length of the press fit. Measurement of the race bore showed that it had expanded .001″ or the extent of the press fit. Further tests are being made using .003″ press fitted races so as to reduce the possibility of the press-fit member becoming loose on the axle.

Third Series of Tests

The results from this group of fatigue tests are shown in Fig. 4. The photograph and line diagram of the test set-up given above the curves indicates that this series of tests is identical to those of the second series except various alloy steels and heat treatments were investigated.

For comparison purposes the curves for the carbon steel are shown. These tests indicate that the 2¾% Ni steel, quenched and tempered and the Cr Ni Moly steel have a fatigue strength with a press fit of 16,000 p.s.i. or ⅓ stronger than the carbon steel of 12,000 p.s.i. The fatigue strength of 2¾% Ni steel without the press fit is 57,000 p.s.i. for a 0.3″ dia. specimen or an estimated 48,000 p.s.i. for a 2″ dia. specimen. Therefore



Curve	Specimen No.	Normal Rolling Pressure per Roller, lbs.	Equiv. Roller Feed across Specimen in threads per inch
a	2-5	0	-
b	Optical flat for comparison purposes		
c	1-3	183	224
d	4-2	210	224
e	2-23	250	40
f	4-1	250	224
g	Cast Iron cylinder bore with one tool		
h	" " " " " " another tool		

Profilograph records, full size, for various types of surface conditions. Rollers used were 7/16" dia. with 1-1/2" contour radius. Scale used is vertical magnification 2000X, where 1/32" = 15 millionths and horizontal magnification 30X, where 1/32" = .001".

Figure 8—Surface finish measurements of rolled axles

in both the case of the carbon and alloy steel axles we find that the press fit condition immediately reduces the axle steel to about ⅓ its strength without the press fit.

Tests on the other alloy steels and heat treatments shown in Fig. 4 were not concluded but the indications are that the fatigue strength will be between 12,000 and 16,000 p.s.i.

Some points are shown on Fig. 4 for the test of 2¾% Ni steel axles both in the normalized and quenched condition having the surface rolled at the press fit portion. Further tests are under way but at this time it is evident that there is a very marked improvement using surface rolling.

THE SURFACE ROLLING OF AXLES

The method employed to surface roll the axle seats at the location of the pressed-on member is shown diagramatically in Fig. 5 and in the photograph Fig. 6. Briefly the axle is rotated about 20 r.p.m. on lathe centers with the rolling device attached to the lathe carriage. The rolling device consists of three or four rollers equally spaced circumferentially about the axle and arranged so that they roll the surface of the axle at a certain pressure as the lathe carriage transverses the axle. The rolling device shown in Fig. 6 is of an elaborate nature for research studies but its construction for use in the machine shop has been considerably simplified.

Locomotive axles 10¾" dia. have been surface rolled in this manner at a pressure of 25,000 lbs. per roller. The axles were ground and then rolled at the wheel and bearing seats. The reduction in axle dia. due to rolling varied up to a maximum of .001".

The effect of plastically deforming the metal at the surface by rolling is shown in the photomicrographs of Fig. 7. The structure shows the stretching and elongation of the crystals into parallel fibres. The hardness of the surface layers of the axle is increased 25 to 50% depending upon the rolling pressure used.

The surface irregularities of axles which were rolled are compared with machined surfaces in Fig. 8. It is obvious that such surface irregularities introduces by rolling may be controlled to give the desired smoothness of surface by using the proper roller feed.

The question of the effect on the fatigue strength of roller pressure, roller shape, and roller feed was investigated[3] on plain specimens 0.3" and 1" dia. where no press fit or stress concentration was present. The effect of roller pressure and shape is shown in Fig. 9 from which one may conclude that roller shape is not very important. The slightly crowned contour roller is the preferred type from the standpoint of the manual operation of rolling. The effect of roller feed is indicated in Fig. 10 from which it may be derived that the surface metal is uniformly cold-worked when the actual contact width between roller and axle is twice the equivalent thread pitch of the roller feed.

Figure 9

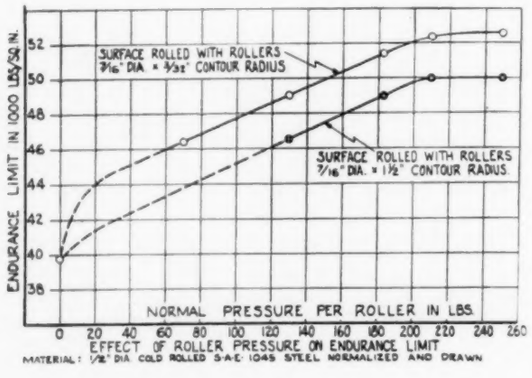
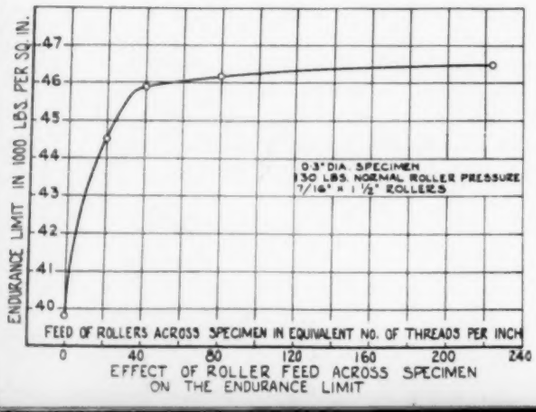

ENDURANCE LIMIT IN 1000 LBS/SQ.IN.
52
50
48
46
44
42
40
38
SURFACE ROLLED WITH ROLLERS 7/16" DIA. × 3/32" CONTOUR RADIUS
SURFACE ROLLED WITH ROLLERS 7/16" DIA. × 1½" CONTOUR RADIUS
NORMAL PRESSURE PER ROLLER IN LBS.
0 20 40 60 80 100 120 140 160 180 200 220 240 260
EFFECT OF ROLLER PRESSURE ON ENDURANCE LIMIT
MATERIAL: ½" DIA COLD ROLLED S.A.E. 1045 STEEL NORMALIZED AND DRAWN

Figure 10



CONCLUSION

It may be concluded from these tests that surface rolling of 2" axles at the press fit portion will give better than twice the fatigue strength of the conventional press-fit assembly. The cost of rolling is inexpensive and a simple rolling device may be attached to any lathe without modifications.

It is believed that an increase in fatigue strength due to rolling may also be obtained with larger sections than the 2" tested. Also the application of rolling, or plastically deforming the material, may be applied to advantage in the design of members in general, where there is a local stress concentration. In order to determine the fatigue strength and investigate the application of rolling to full size axle assemblies the Timken Roller Bearing Company has purchased equipment suitable for testing 12" axles in reversed bending fatigue.

ACKNOWLEDGMENT

We are indebted to the staff of the railroad department of the Timken Roller Bearing Company and to Professor E. L. Ericksen who provided facilities at the University of Michigan. Acknowledgment is also due Dr. S. Timoshenke for his valuable suggestions during the progress of this work and to Dr. J. L. Maulbetsch for his analysis and assistance in the tests.

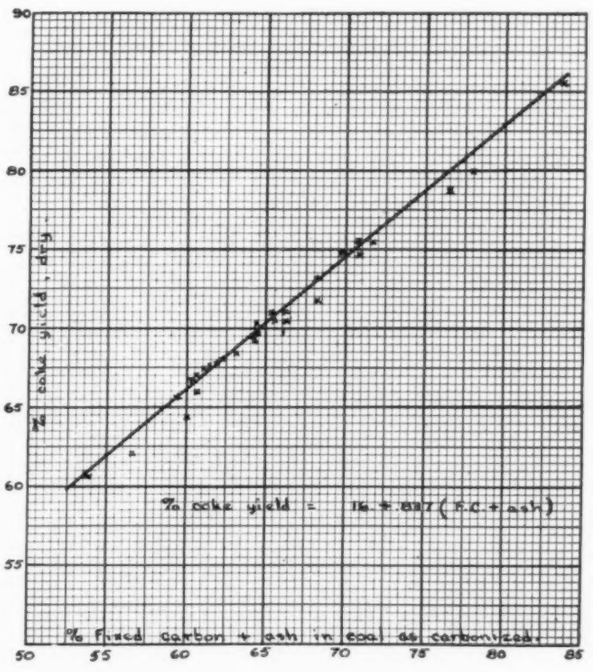
The Determination

OF YIELDS IN THE COKING PROCESS

▲ COAL is our principal source of heat and power, and therefore constitutes an extremely important factor in industry. Its Conservation is a vital issue for the continuity of our industrial operations. It is therefore of paramount importance that the properties of coal which affect its use be studied and generally known, so that the highest economies of operation be attained.

The use of coal for direct generation of heat, and its performance in this application has received wide study. The properties of coal affecting its use in this way are well known, and this knowledge has been widely disseminated. In marked contrast to the availability of this data, however, is the paucity of information on the properties of coal pertaining to its carbonization, and the results to be expected. This state of affairs is even more surprising when one considers the importance of the carbonizing industry, the large quantities of coal used in the industry, and the widely varying results obtained from various coals, with the added consideration that the conservation of coal, as well as the growing sentiment for smoke abatement, renders a further extension of coal processing very desirable.

Figure 1



Realizing the dearth of information on the carbonizing properties, the American Gas Association, in 1928, established a cooperative agreement with the Bureau of Mines, through which an investigation of such properties was started. Beginning as an investigation into methods of testing, the project has been followed through the complete testing of thirty coals. The method finally developed by the Bureau of Mines for this testing is described in Monograph No. 5 of the Bureau of Mines, together with tabulations of results from the thirty coals. Detailed results of each coal are also available in various technical papers of the Bureau of Mines, a list of which is appended to this article.

The carbonizing tests on the thirty coals were made at various temperatures, ranging 500° to 1100° C. (932-2012°F.). In addition to determination of yields and quality of the carbonization products at each temperature, the coals were subjected to chemical and physical tests, including complete chemical analyses, petrographic examination, assay distillation, etc. The series of tests at different temperatures shows the operator to what extent returns can be bettred by variation in oven heats. The survey has opened a veritable mine of information to operators and engineers of coke plants, gas plants and coal mines, and deserves careful study, while plants with large scale operations should find the installation of an outfit for individual testing extremely valuable in the selection of coals, determination of blends, and effect of coking time, temperature, etc. A knowledge of the properties of various coals such as available from these tests is invaluable to a large consumer, because it enables him to study yields and quality of by-products in connection with the cost of the coal, thus renderizing possibly an intelligent choice.

Tests may also bring to light various characteristics which might cause trouble or damage to the plant. For example, the series of tests showed clearly the variation in swelling characteristics of the coals; low-volatile coals showed a considerable swelling, while medium-volatile coals also gave some, particularly at the higher carbonizing temperatures and rapid heating rate. The results also showed that the swelling occurs in the early part of the coking period. A knowledge of these properties might forstall serious damage to coke ovens.

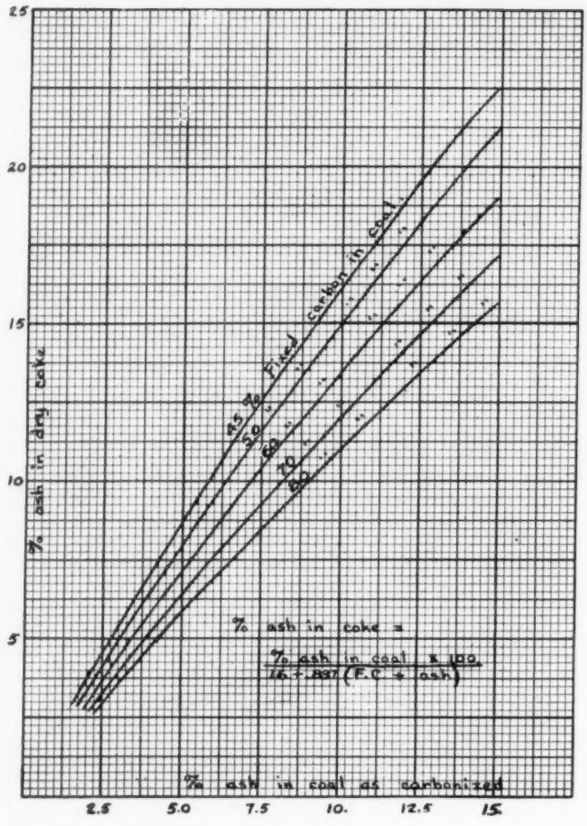


Figure 2

The thirty coals tested include ten high-volatile gas coals; six high-volatile coking coals of which three are low-rank coals high in oxygen; four medium-volatile coking coals, two low-volatile coking coals, three blends of high and low volatile coals, and two coals in both washed and unwashed condition. Coals were selected from which full-scale results were available from commercial plants. Comparison of tests results with commercial plant results have shown substantial agreement, so that the tests, properly interpreted, may be relied upon to furnish an accurate indication of results to be expected from full scale operations.

An independent study of the results obtained from the series of tests has brought out several points which are worthy of note. Various relationships have been found which may render the approximate judging of a coal comparatively simple. While further tests may show the need of revision in these deductions, the present series of tests seems to bear them out quite closely. It is therefore with some reservations that the following is offered.

COKE YIELD

The coke yields obtained from the various coals are closely proportional to the rank of the coal as measured by its fixed carbon, running 102-113% of the fixed carbon plus ash content of the coal as carbonized. Figure 1 shows the coke yields, dry plotted against fixed carbon plus ash. The straight line satisfies these points nicely, and the formula for this relation may therefore be developed as:

% coke yield, dry, = 16+.837 (C+A)

Where C equals % of fixed carbon in coal as carbonized.

A equals % of ash in coal as carbonized.

The ash content of the coke, which equals the ash content of the coal divided by the coke yield may therefore be expressed:

$$\%\ \text{ash in dry coke} = \frac{100\ A}{16 + .837\ (C + A)}$$

with symbols as above. This formula has been ploted in Figure 2.

Coke yield drops as the carbonizing temperature is increased up to about 1650° F., due to the more complete driving off of the volatile matter, which reaches a minimum of about one-half percent at this temperature. The carbon content of the coke increases, and the B.T.U. per pound of coke decreases simultaneously. Above 1650° F., the coke yield increases slightly due to carbon deposition. These variations, however, do not seriously affect the above formulae as applied to actual coke plant practice.

The tests also show that, other things being equal, coke from high-rank (low-Volatile) coals is stronger than that from lower ranks, and that strength decreases and density increases as the temperature of carbonization increases.

Sulphur content of the coke has been plotted against sulphur content of the coal in Figure 3, and these points follow closely the line expressed by the equation:

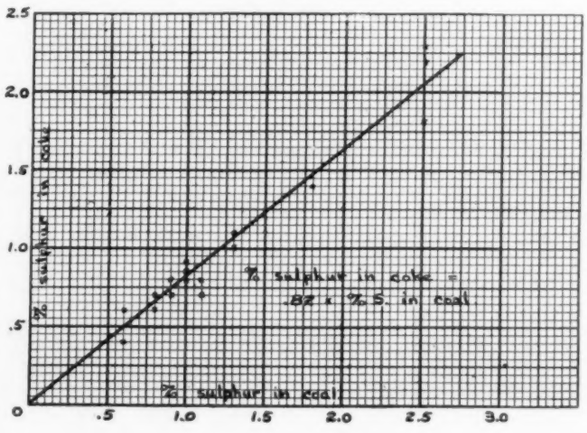
% sulphur in coke = .82 × S.

where S = % sulphur in coal as carbonized.

GAS YIELD

High-rank Appalachian coals give gas yields roughly proportional to their volatile matter content, but for coals high in oxygen, the proportionality does not hold. High resin content also increases gas yields. Operation and condition of coke ovens cause even greater variations. Accordingly, no factor could be found to serve as a definite indicator of the gas yield to be expected. Yields ranged from 9300-11000 cu. ft. of gas per ton of coal, with the majority falling between 10000 and

Figure 3



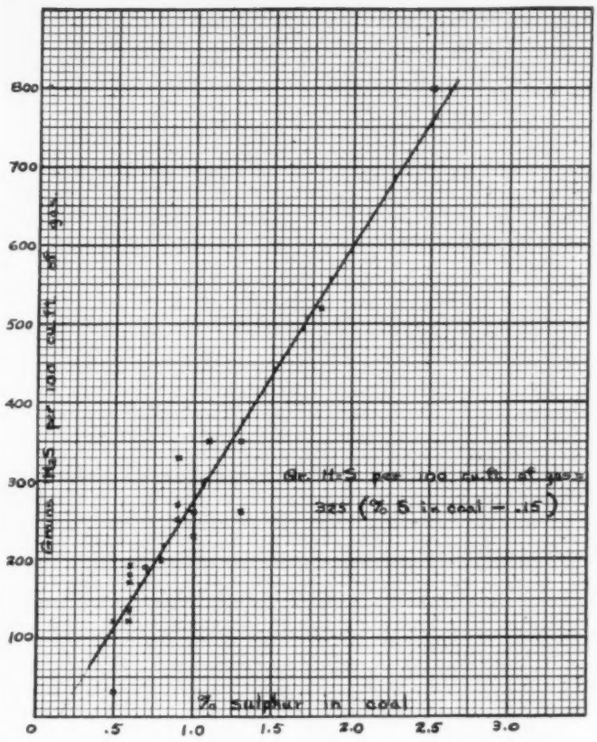


Figure 4

10500 cu. ft. per ton. This volume, for a given coal, varies directly with the coking temperature at the rate of about 1500 cu. ft. per ton for each 100° F. temperature change.

Composition of the gas, for a given coal varies as follows:

Hydrogen in gas increases with carbonizing temperature;

$C_2 H_6$ and $C H_4$ decrease with temperature increase;

CO increases slightly as the temperature rises;

Btu. per cu. ft. drops as the temperature rises;

Specific gravity of the gas drops as the temperature rises.

The total Btu. in the gas from one pound of coal runs 2800-3400, increasing with volatile content of the coal, and with the temperature of carbonization. The average seems to be satisfied by the equation:

Btu. in gas per pound of coal = 2135. + 29.5 V.

Where V equals the % volatile in the coal. More than 3400 Btu. in the gas from a ton coal indicates excessive degradation of tar vapors by high temperatures. Btu. per cu. ft. of gas varies with the volatile content of the coal, and specific gravity of the gas varies with the volatile content in a relationship closely approximating:

Spec. Gravity of gas = .15 + .0076 V.

Sulphur content of the gas depends on the sulphur in the coal. Results of the series of tests show the gas to carry a range of 100-389 grains of hydrogen sulphide per 1% of sulphur in the coal. Figure 4 shows the results in grains of hydrogen sulphide per 100 cu. ft. of gas against percent of sulphur in the coal as carbonized. Again the relationship is closely approximated by a straight line, which may be expressed by the formula:

Grains H_2S per 100 cu. ft. of gas = 325 (S — .15)

Where S = % sulphur in the coal as carbonized.

TAR YIELD

The yield of tar is influenced by the rank and grade of the coal used. Low and medium volatile coals give low yields as do coals high in oxygen. Fig. 5 gives Tar Yields plotted against the percent of volatile matter in the coal. The points falling far from the line represent coals of a widely varying oxygen content. Recognizing this factor, the equation offered to indicate Tar Yield is as follows:

Gal. Tar per ton of coal = .51 (V-10.5) — (O-8.)

Where V = % volatile matter in coal as carbonized

Where O = % oxygen matter in coal as carbonized

The yield of tar for a given coal drops as the carbonizing temperature is increased. Hot or empty oven tops also decrease tar yields, due to the tar vapors cracking up. Increasing oven temperatures also changes the composition of tar, the naptha, creosote and anthracene contents dropping, and the pitch content rising, while the specific gravity also increases.

LIGHT OILS

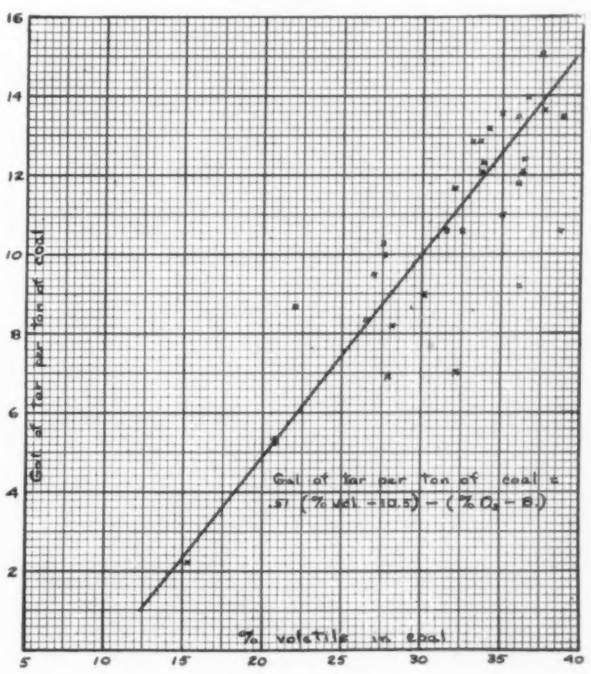
The yield of light oils shows a direct proportionality to the volatile content of the coal, closely approximated by the formula:

Gal. of light oil per ton of coal = .13 (V-8.5).

Figure 6 shows this relationship.

For a given coal, light oil yield increases with temperature of carbonization up to 1650° F. beyond which

Figure 5



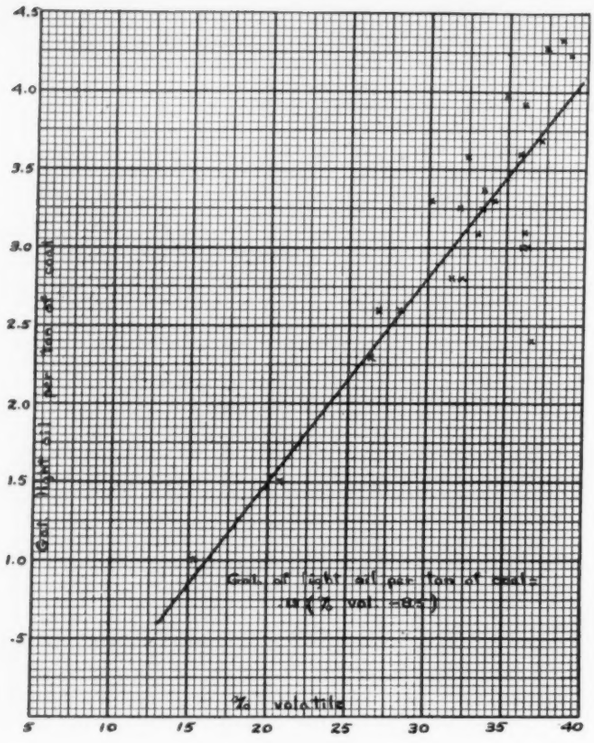


Figure 6

the yield drops. The composition of the light oil also changes the percent of benzene increasing with temperature, while the percent of Toluene increases to a maximum at 1475° F. and then drops.

Efficiency of recovery which depends on many factors of plant construction condition and operation, may seriously affect light oil yield, so that any prediction of yield based on coal quality alone must be used with care.

AMMONIA

No consistent variation in yield of ammonia with rank of coal is apparent. Liquor recovery is proportional to the oxygen in the coal, ranging from 58-104% of the total oxygen by weight in the coal as carbonized. Ammonia yield seems to vary with the nitrogen content of the coal, but not in proportion. 18% to 30% of the nitrogen in the coal appears in the ammonia, but the yield is so affected by moisture and by the ratio of oxygen to hydrogen in the coal, by hot oven tops, and air leakage etc., that no simple deduction can be made.

These relationships may seem more or less crude, and may prove to require revision. However, they present an approach to a subject concerning which little seems to be known, and less said, if they should serve to stimulate investigations along this line, they will have proved of value. At least, they are a step towards rationalization of a highly empirical subject.

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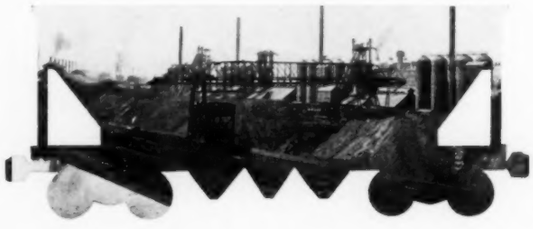

Commercial Welding

AS APPLIED TO STEEL MILLS

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▲ IF IT were not for the Iron & Steel industry, the resistance welding industry would not exist and would never have been born. It is a conservative estimate that over 99% of all the resistance welders in existence are used for welding iron or steel, or some of their numerous alloys.

But while the iron and steel industry was the father of resistance welding, it is evident that the offspring has grown up and become a powerful aid and ally of the parent. So far as we can learn, the first proposal to use resistance welding within the steel mill itself was at the plant of the Inland Steel Co., of Indiana Harbor about 1920, and was for plant maintenance only. They desired to repair broken rollers by flash welding the broken necks or gudgeons back into place. These broken parts occured in a wide range of sizes and the average cross section to be welded was 82 square inches.

No such large flash welders had been built at that time, and owing to the enormous die equipment that would have been required to cover the entire range of sizes of work, and because of doubt in the mind of the plant engineer that sufficient power could be obtained to operate such a large welder, the proposition was abandoned. The proposition was revived again about 1928, but for the same reason as before, was abandoned a second time. But flash welders were fabricating a large percentage of the output of the steel mills into automobile and truck members into barrels, paint and milk cans, lockers and cabinets, metal furniture pipe and many other articles. The first actual resistance welding to be done in the Steel mill itself so far as we know, was in Ashland, Ky., nearly two decades ago. They attempted to spot weld the ends of rolls of wide sheets together so that it could be drawn continuously through pickling or annealing operations. The attempt was only partially successful, owing to lack of knowledge and experience in the design, operation and maintenance of the welding equipment, and because of new problems arising in the handling of the stock to and from the welder.

The next several proposals were to flash weld the ends of rolls of sheets together for continuous additional rolling, pickling, annealing, etc., and to save crop ends. These attempts were doomed to failure because they attempted to make the welder and flash trimmer travel along with the work while the clamping, welding, and flash trimming and unclamping was done, a distance varying from 80 to 120 feet,then the entire outfit was brought back again for each successive weld.

The time element necessary for welding and trimming was finally obtained, whereby the welder and trimmer could remain stationary without interrupting the rolling process, by providing slack pits in some cases, and swinging drums in others, whereby the accumulated stock would be temporarily cared for while the weld was being made and trimmed.

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The first installation of this nature with which we were personally connected was in Jersey City and it flash welded high carbon steel sheets together and the rolling was then continued until the stock was of proper gauge for safety razor blades.

Another installation in Michigan had a rather unique flash remover in that the flash was ground off flush by means of motor driven, high speed emery wheels, the faces of which were inclined at an angle of 45 degrees with the upper and lower sides of the work, which avoided having to dress the faces of the wheels.

Cold strips up to 72″ wide have already been successfully flash welded together and a steel mill is now considering the flash welding of sheets 92″ wide.

Since the average mill can handle a billet of only about 4000 pounds, on each end of which there is a

crop end loss, if subsequently rolled individually, the desirability and necessity of welding the ends of these sheets for continuous operations is obvious. The welding operation itself is comparatively easy. Trimming the flash or upset so that it is practically flush with both sides of the sheet is a more difficult matter for there are several variables that enter into it as follows:

First—The sheet may not be of uniform thickness throughout its entire width. Now, since it has not been possible up to the present time to build a differential flash trimmer it follows that where the sheet is below normal gauge, the trimmer will leave a fin standing up to the height of the normal gauge and where the sheet exceeds normal gauge a groove will be left by the trimmer.

Second—The cutting tools of the trimmer both above and below wear away constantly, making it necessary to adjust them frequently.

Third—The temperature of the flash or upset at the instant of trimming. If the trimming could be done right in the welder while the flash is still red hot, it would cut very easily, but the present cutting tools will not stand up under this terrific heat. So present practice is to unclamp the sheet from the welder dies, move it along several feet to the trimmer, clamp it again and then trim it. By this time the flash is cold and nearly as hard as carborundum. Because of this hardness, the cutting tools dull rapidly and if not dressed often, may pucker, and some times tear the sheets.

Fourth—The wider the sheets, the longer the gibs of the trimmer and the greater the deflection at the centre, thus sometimes leaving a fin standing along the second and third quarter of the sheet, on both sides. Now these fins being quite hard as described above may cause the next set of rolls to jump and spread, thus increasing the gauge of the sheet from that point. Furthermore, these fins may make indentations in the rolls themselves and thus necessitate redressing them so they will not mark all future sheets. There is a great opportunity for someone to develop a combined flash welder and flash trimmer where the trimmer will function the instant the weld is made, while it is still hot, utilizing the clamping of the welder itself, thereby cutting the standing time of the sheet more than in half and thus requiring shorter slack pits or fewer swinging drums. Also such a device would produce more uniform work, would not spread or mark the rolls, or tear the sheets.

Preliminary work has already been done along this line and plans are now in progress to supply the iron and steel trade with a combination flash welder and trimmer for cold strip that is radically different from and far superior to any such device now in existance.

Since patents have already been applied for, we can describe the device briefly in general terms.

The weld will not be made at right angles to the longitudinal axis of the sheet. It will be made on a bias at an angle of from 20 degrees to 30 degrees depending on the thickness of the sheets. The thinner sheets require the lesser angel while thicker sheets require greater angles. The work is unclamped immediately on the completion of the weld and the forward rolls take up the slack, drawing the sheet through large ,wide trimming knives fixed opposite one another above and below the sheet. These trimming knives are likewise set on a bias at angles of from 20 degrees to 30 degrees with the sheet, but the angles are opposite from those of the welder. Now, as the weld is drawn between the knives a bias cut with an even shaving effect is produced which leaves the weld flush and does not pucker, or tear the sheet. Furthermore, the bias cut travels uniformly from one end of the knives to the other requiring a minimum of power to draw the sheets through the trimmer and a minimum of maintenance of the knives themselves.

The only halting of the sheet is for clamping and welding. The trimming occurs as the rolling is resumed. Now, because of the bias only a little at a time of the weld goes under the rolls. No jumping or spreading or indenting of the rolls occurs, and greater uniformity of gauge of the sheets are secured.

Suggestions and advice from you regarding this special device will be welcomed and appreciated.

Another outstanding use of flash welding in steel mills is to join pipe end to end into 40 ft. 60 ft. and sometimes even 80 ft. lengths in the mill instead of the old conventional 20 foot lengths. These longer lengths reduce the amount of threading required, reduce the number of collars and also reduces the labor costs to lay the pipe line by reducing the number of joints to be welded or tonged.

Wire drawing mills often use resistance welding to fabricate their products into wire fence, reinforcing mats for roads, bridges and culverts, grids, drying racks and many other uses.

Other mills weld their product into steel joist, steel studding, metal flooring, piling and other articles too numerous to mention.

Because of shipping difficulties, it is sometimes necessary to do subsequent welding in the field near where it is to be used. This occurs on very large projects such as Boulder Dam and Metropolitan Water District of Southern California. On the latter project, thousands of reinforcing rings 18 feet in diameter were used. At first the rings were welded in Los Angeles mills. When they attempted to ship these rings by rail, they bounced off the cars on curves and when coupling cars inadvertently were soon scattered all along the tracks and on tops of houses from Los Angeles to Parker Dam. Finally, the railroads refused to handle any more rings because of the many accidents they caused and the welding was then done along the right of way of the district near where the rings were used.

Inhibitors

AND THEIR PROBABLE MECHANISM

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▲ AS you know, steel or iron accumulate a scale or oxide in any heating operation, such as, heating for rolling, heat treating, annealing, etc. This scale must usually be removed before further processing particularly if the further operations are forming cold. Also for any further coating as galvanizing, tinning, etc.

Pickling in an acid solution is the fastest and cheapest method universally used. But it happens that while the steel is being pickled to remove the scale, the acid becomes particularly active on the steel proper. This latter reaction is unnecessary, unproductive and inefficient.

WHAT AN INHIBITOR IS

An inhibitor is a material added to the acid bath to limit or almost totally obliterate the action of the acid on the steel proper while allowing the pickling of the scale to continue.

The effect is almost magical as with the modern synthetic chemical inhibitors such an infinitely small quantity introduced into the solution causes such a marked and vast influence on the total operation. When figured in proportion to the total amount of solution, parts as small as 1/20,000th, do the work with very high efficiencies.

The advantages to be gained through the use of an inhibitor and particularly a synthetic chemical inhibitor are many. Some disadvantages in particular applications will also be honestly set forth.

Let's take the crudest form of pickling, that of pickling billets for the removal of scale and the development of seams, surfaces, etc. The consumption of acid in this process is enormous and, therefore, any increase in the efficiency of the inhibitor over another inhibitor will produce large savings. In billet pickling there is also quite a variation of steel analyses going through the tank at various times without much variation in technique. Then also an inhibitor should perform with a high efficiency on all carbons and changes in alloy.

When we say the crudest form of pickling we do not mean that it should be crude, but with some operators, the finish of the surface is not particularly stressed. Discoloration may not be important but the formation of excessive smut on alloys is. A good clean surface is desirable to disclose all the seams. Even though some of the billet tanks are outdoors, the suppression of fumes is desirable.

COLD DRAWING BARS

Bars for the cold drawn mill must be descaled as the scale would be very abrasive on the dies. Here again the material being pickled varies greatly from charge to charge.

The production in the pickle room must anticipate the production of the draw benches and the orders come through with different analyses at every lift. One minute it may be 1020 while the next it may be 1112 or 3140. There is hardly time to totally change acidity, temperature and freshness of tank for every lift. Some good picklers do try to concentrate their alloys in a fresh tank and their plain runs in the older tanks.

An inhibitor to do good service in the cold drawn mill should cover these conditions fairly efficiently. In other words, if we can't adapt the procedure to the product we must adapt the product to the procedure as nearly as possible.

Of course, all steels have a different pickling rate and even steels of the same analysis pickle differently depending on their method of manufacture, stresses, cooling rates and heat treatments.

The speed of pickling varies greatly with temperature, as you all know, doubling about every fourteen to seventeen degrees. At 212 the speed on ordinary low carbon open hearth is about five times as fast as at 180° F.

On alloys and on Bessemers the rate increases much faster and, therefore, even 180° is sometimes too hot for a good job. A strong inhibitor film is a good aid, however.

Scales vary. Chemically there are only three common variations of iron scale. The ferric oxide, Fe_2O_3, containing the most oxygen would most naturally be found on the outside layer. Fe_3O_4 is the next, and FeO, ferrous oxide, the leanest and the closest to the metal. FeO is very hard to dissolve when remaining as such and, therefore, the difficulty in pickling some heat treated bars.

But when FeO is cooled slowly it disintegrates around 1100° F. into some Fe and Fe_3O_4. With this mixture there is a more rapid solution than Fe_3O_4 or Fe_2O_3 alone. This accounts for the apparent pickling of the

scale from the under side as can be observed in a beaker. The old contention is that the steel pickles away from under the scale. A further theorizing on this subject will be taken up under Galvanic Couples.

A heat treated bar, then, one in which the FeO scale has been arrested as such in the quench, and then is drawn somewhere below a 1000° F. may have a particularly bad scale to pickle. If there are bare spots where the scale has fallen off in the quench or handling there may be localized etching and this may be greatly increased by concentrated action of electric currents.

In the pickling of forgings such as done in the automotive plants the question of various analyses comes up again. Sometimes the addition of rock salt to a sulphuric acid pickle aids in the solution of some of the more complex alloy scales. The salt converts some of the acid into hydrochloric acid which does aid the solution of chrome scales where plain sulphuric acid may be almost dormant.

Heat treated scales are also common on forgings. It may be necessary to lower the temperature and resort to slower pickling.

Wire rods have an ideal scale when finished at not too high a rolling heat and then allowed to cool slowly. The chief disadvantage is in the tightly matted coil not getting sufficient circulation of acid to the inner layers. This takes an inhibitor to protect the exposed surfaces while the inner ones are still being cleaned.

There is usually an assortment of analyses traveling through a wire mill at the same time and here again the pickle room may be working on a basic open hearth low carbon batch one hour and then on some high carbon and next some bessemer. Each of these has different pickling speeds and should be done at different temperatures. You sheet men don't know what an easy job you have where the material comes all the same analysis all day long.

A good strong inhibitor is a great boon when these changes come along so rapidly that the acidity cannot be lowered or the temperature cut; an inhibitor that will lick bessemer as well as open hearth; and one that will have attaching strength in the presence of a lot of hydrogen action; and one that will stand a lot of heat, if necessary, without breaking down.

Strip Mills have a relative easy job of pickling. The scale is fairly uniform but some protection is needed for the uncovered areas and particularly to prevent the formation of smut which would eventually result in a gray sheet after cold rolling. It seems to be the practice of pickling quite hot, for the hotter the pickle the more the production. Here an inhibitor that stands heat is a positive necessity. Also if the inhibitor stands boiling without signs of breakdown you can expect a much longer life at 180°. Finish is important so the inhibitor must not stain due to its own impurities.

GALVANIZED SHEETS

Sheets, previous to galvanizing, are pickled to remove scale. The question of how much inhibitor to use to protect the surface, prevent smut, and still allow the required etch varies somewhat. A totally inhibited bath will eliminate blisters but will also eliminate the etching which is desired for a tight coat. A happy medium has to be struck where the inhibitor action is only about 85% to 90% perfect. This can be done by using the inhibitor in proportions about one third to one fifth as lean as would be used for ordinary pickling. Even at this spare ratio the effect on blisters, smut and fumes is still pronounced.

No inhibitor is recommended in the final hydrochloric pickle as this is decidedly a final etching bath.

The purity of an inhibitor for sheet pickling cannot be over emphasized. No tarry sludges which leave stains or tar specks can be tolerated. Also the inhibitor film should be totally soluble or dissipated in the rinse water or easily burned off in the flux without leaving a soot to prevent coating.

The pickling of sheets for tinning should be done with the same lean inhibitor proportions.

PIPE

In the pickling of pipe we run into another problem. To get the ideal galvanized job the surface of the pipe after pickling should be clean, free of smut and smooth, not pitted. A smooth surface uses less spelter due to proper drainage and yet the minimum coating is no thinner than on the minimum spots on a rough pipe. To get this smooth finish demands the use of an inhibitor. Also it prevents the excess formation of smut.

On the internal bore, however, as I recall the practice, there may be spots of fused silica picked up from the furnace floor when heating the skelp. As silica is insoluble in sulphuric acid it is impossible to pickle this off without actually pickling away some of the steel underneath it. 100% inhibition would prevent the pickling of this steel, therefore, here again a happy medium must be struck between 70% and 85% inhibition.

In reverse forming where the silica is on the outside of the pipe the tumbling and handling aid its break up. Running the pipe through straightening rolls previous to pickling helps break the silica scale into smaller areas thereby reducing the time factor in pickling.

The acid content within the bore of a pipe should be sufficient to do the entire pickling on the area of that bore or a slushing of fresh acid is resorted to in the middle of the pickle exposure.

Seamless tube pickling is very much like pipe pickling with the exception of the welded on silica slag. Of course, tubing runs into higher carbons and alloys.

In the commercial job galvanizing shop it is almost hopeless to use a real high powered inhibitor. You want some etch and as the activity of the acid changes for different temperatures and these are constantly varying together with the analysis of the work, any percentage of inhibition adopted at one moment may be off at the next.

The only salvation is to adopt one of the foaming agents alone which will blanket the top of the bath and in addition lend a slight inhibitive value to the solution.

Coming back to inhibitors, lets briefly trace their development and from that see where we are evenrually heading.

Flour and starchy materials have been used as pickling inhibitors for a long time. It is hard to trace thier actual origin. Whether it is just the additional film strength or a change of surface tension in the liquid, that does the work, or whether there is some organic

chemical present of the same nature as some of the synthetics we make today, is a question. We do know that a mash solution that has been allowed to ferment for 24 hours is better than a fresh solution. This may be due to a breaking up of the flour into a colloidal solution or it may be due to the formation of alcohols and aldehydes. Flour, nevertheless, is a very weak inhibitor and although cheap must be used in large doses. The film strength of flour is also weak and while performing fairly well at moderate temperatures on low carbon steel may suddenly go to pieces when some more active steel is introduced and hydrogen evolution starts.

SURFACE TENSION

If we can picture it in this way: Let's say we have a sheet of steel suspended in an acid solution. The acid starts to attack the steel forming hydrogen bubbles. By changing the surface tension of that solution the hydrogen bubble will tend to cling to the surface of the steel instead of immediately releasing itself and floating to the surface. When this succession of bubbles, and not even bubbles, but this succession of a continuous deposit of hydrogen pockets, is held onto the surface by the glutinous material, then there is no more pickling as the acid cannot reach the metal.

When the temperature is raised, which may weaken the film strength as well as increase the activity of the hydrogen, the film may break and the entire deposit be rinsed off by the flow of bubbles. There is really no strong affinity in the first place, and no strong attachment after the attachment has taken place.

Flour also due to its change in surface tension does form somewhat of a foam or blanket over the surface of the bath.

Blankets have the advantage of withholding some of the acid fumes from the atmosphere. As hydrogen bubbles rise to the surface of the solution they bring with them some SO_2 or SO_3, acid fumes. These are expelled into the atmosphere and do the corrosive work on the buildings and the nostrils. A foam forming ingredient entraps the acid fumes, if not all of the hydrogen, and when slushed by agitation puts this acid back into solution.

All foam forming materials are inhibitors to a varying degree but depend mostly on the surface tension principle and, therefore, are comparatively weak.

A real inhibitive bath does not need a foam. If the inhibitor is doing its work down on the surface of the steel, then there is no hydrogen formed and the foam is unnecessary. Foam, therefore, is an admission of an inefficiency.

Practically, however, some of the operators prefer a partial foam content just as a safety in case they get a sudden switch in steel. To some inhibitor bases it slightly enhances their value while to others it detracts.

About 1921 or 1922 a German Compound called "Picollett" came on the American market. This was the first of the organic class of chemical inhibitors. It had great strength when compared with natural inhibitors such as flour, etc. Then came K 99 and other American products. Most of these had some disadvantages such as tarry slimey residues left on the steel, stains, high breakdown due to heat, etc. They also left a greasy scum on top of the bath which was more apparent with those derived from oil tars or sludges.

To get solubility you had to dissolve some of them in the concentrated acid first. All in all they did a lot of good if their deficiencies didn't overtake them.

The point here is, that there were in some of these crude products, families of chemicals, which if isolated and determined might lead to an orderly research to find just what an inhibitor was and why.

Formaldehyde was known to do some good but also is very weak. Here we are getting to definite chemical compounds with all their purity minus the objections of by-products.

Now if you can make a complex, chemically pure compound with very great efficiency and cheap, that will satisfy all the requisites of an inhibitor, then you have greatly increased the use, for you have broadened the field.

Certain modern synthetics today do have all the requisites, but the search is never ended for still more efficiency.

SPECIFICATIONS

Let us enumerate here what the specifications of a good inhibitor should be.

Perfect solubility
- In dilute acid solutions
- Immediately. No chunks or floating particles.

No impurities.
- No greasiness.
- No staining.

Must be cheap relative to its efficiency.

Preferably a powder.

Have high efficiency over a wide range of steels.

Have strong attachment power under adverse conditions.

Have a low breakdown over prolonged exposure.

Have no breakdown at high temperatures.

Have good coverage after attachment.

Leave no residual film that will interfere with future operations.

You will see how these requisites gradually fit into the theories and research developments discussed here later.

CHEMICAL REACTIONS

As mentioned previously there are three common scales to be removed from steel which has been heated. There are more variations if you consider the hydroxides, etc., produced by rusting and other exposures.

With plain iron and sulphuric acid the reaction is:—

$$Fe + H_2SO_4 = FeSO_4 + H_2$$

The three scales in their successive enrichments in oxygen show reactions as follows:

$$FeO + H_2SO_4 = FeSO_4 + H_2O$$

The by-product is water and not a bubble.

Going on to the other two oxides:

$$Fe_3O_4 + 3H_2SO_4 + H_2 = 3FeSO_4 + 4H_2O$$

$$Fe_2O_3 + 2H_2SO_4 + H_2 = 2FeSO_4 + 3H_2O$$

Note that in the first equation where you are pickling iron, the by-products of the reaction are of course ferrous sulphate and HYDROGEN:

In the second equation WATER, No hydrogen; and

in the third and fourth, no HYDROGEN, but hydrogen is being absorbed on the left side to reduce the higher oxides.

Then we can almost formulate the conclusion that when you see Hydrogen coming to the top of a pickle bath, metal is being attacked.

REACTIONS MUST BALANCE

Coming back to the practical, I have sometimes heard the expression, "Well we stopped the fumes but we didn't save acid" or "We saved acid but didn't save steel."

If you say these things it is because you didn't collect enough figures to show them, not that they didn't exist.

There is a definite relation between the amount of iron that a certain amount of acid will consume, and just how much hydrogen that will form, and how much ferrous sulphate. These relations are constant. Any discrepancies in the figures show inaccuracies in gathering the data, or leaks or dumps after the saving has been made.

You can rest assured that 98 pounds of 100% sulphuric acid will always consume 56 pounds of iron, no more, no less. Also that 98 pounds of acid will liberate 2 pounds of hydrogen when working on iron, and that 152 pounds of ferrous sulphate are formed. If you include the water of crystallization, then there are 278 pounds of ferrous sulphate crystals formed.

Then roughly, since 66° B. acid is only 93% pure, you must save approximately ½ pound of steel every time you save 1 pound of acid; of course figuring acid dumped at the end of the run, etc., being equal.

May we advance some theory on the working of the pickling process and how an inhibitor fits into the same scheme of thinking?

Between any two different materials in an acid bath there is an electromotive force or a voltage generated and if these parts are short circuited to each other as they are when welded into the same piece of steel, then there is a flow of current between the two different ingredients setting up an electrolysis and corrosion. Hot acid solution is an excellent electrolyte, therefore, if you have scale and iron welded to each other and exposed to the hot acid solution you will get an electrolysis with scale as one pole and iron as the other. The iron is the positive or anode while the scale is the negative or cathode.

Since current takes the shortest course, the electrolysis is between the underside of the scale and the steel, not the top side. It starts at some crack or opening in the scale where the acid solution can enter. This is why we get the impression that hydrogen is being generated under the scale and actually pushes it off. The electrolysis is working wherever the acid solution can permeate between the scale and the iron. A certain amount of hydrogen is being generated in this crevice and some of the acid acts on the iron momentarily and, therefore, the slight bubbling action of hydrogen coming to the surface when a fresh piece of steel has been inserted in an acid solution, even though that acid solution may be inhibited.

As the solution of the bond between the scale and the iron is finally completed, the piece of scale drops off and drops to the bottom of the tank. From here on, the solution of iron oxide in a sulphuric acid bath is fairly slow, as is evidenced by the presence of scale in the residue at the bottom of a pickling tank when the tank is dumped. While the scale is attached its solution is accelerated by the electrolytic pressure varying from approximately ½ volt to a volt and a half, while thereafter it is straight chemical solution.

Between any other two ingredients within the steel there is also a definite potential difference. Impurities like sulphides, phosphides and alloys, like chrome carbides and nickle, etc., all have definite potentials in relation to each other and in relation to iron.

The carbon in steel is present as the iron carbide, Fe_3C, or cementite. There is a potential difference between iron carbides and iron, in which the iron is the anode or positive and the carbide is the cathode or negative. The acid in this case attacks the iron leaving the cathode untouched. The iron area immediately surrounding a cementite particle is dissolved until the cementite particle is entirely free. The iron dissolving leaves a pit while the cementite or carbide sets itself on the surface as a smut. We note that the higher the carbon steel the more violent is the pickling, therefore, also the more numerous the reactions.

The solution of the steel under the scale is only momentary and does no real damage to the steel surface, but where the cementite is located the solution of the iron surrounding the cementite particle goes on, and does the real damage as to pitting. It is, therefore, the stoppage of this second reaction that we are interested in.

INHIBITOR INSULATION

An inhibitor is no more than an insulating substance dissolved within the acid bath, which has a high positive charge, waiting to be attracted by the negative cathodes or carbides. As the electrolysis gets in motion between the iron and the iron carbide, the inhibitor particle travels in the direction of the current and attaches itself to the iron carbide thereby forming a slight film over all the cementite areas, preventing any further flow of current.

If the current is stopped, the electrolysis is stopped, solution of steel is stopped, hydrogen is stopped and waste of acid is stopped.

All the more modern inhibitors resemble substances like Bakelite, but must have various other additional characteristics to make them operate in an acid bath.

It would be natural to suppose that a *good* insulator could insulate against such voltages as exist, with a very thin film, while a *poorer* insulator would take a much heavier film. This is evidently the case with inhibitors for we find that with slightly different molecular arrangements we may have a very strong inhibitor, compared to its first cousin, a very weak one. Some films may be heavy and yet porous, other films may be heavy and yet not have a high dielectric strength. Some films may be strong at moderate temperatures but do get weaker at higher temperatures. The best film is one that will be the highest dielectric, with a minimum deposit. This means complete coverage, non-porosity, strong attachment, and stability at all temperatures.

DEPOSITION ATTRACTION

Let us consider these facts separately; for instance, if your inhibitor is floating around in the solution but does not have a strong positive charge, which positive charge is certainly influenced by the size of the negative side of the molecule, then it will not have a great attraction for the negative cathode area. Therefore, attraction is the first vital factor.

Second, coverage. We find that two inhibitors of approximately the same sized molecular construction, may have a different efficiency as an inhibitor. This is largely due to the arrangement of the molecule and not solely due to its size. This reflects back then on the insulating power of a certain thickness film. The attraction also is a factor in the coverage, for an inhibitor with a strong attachment cannot be brushed off by a wild evolution of hydrogen as easily as one with a weak attachment.

Going back to the older inhibitors like red dog flour and some of the gelatinous materials which are usually used in fairly rich quantities to produce a result. They have not any great attraction to form a protective film but do operate if the conditions for deposition are ideal. If you have a moderate temperature and low carbon steel, they may eventually take hold and do some inhibiting. The minute the conditions are varied, or a high carbon steel is introduced, the evolution of hydrogen is so brisk that the inhibitor film is literally wiped off the surface and its protection ceases. Their tenacity to cling to the surface after attachment is very meager.

This is demonstrated again by the fact that sometimes with a fairly active steel or a hot solution, the inhibitor fails to sit. If the load is removed from the tank for a few seconds and then redeposited in the tank, this slight cooling of the sheet with the inhibitor solution thereon, allows the inhibitor to sit. After it is once attached the inhibiting action seems to go on without any trouble.

MOLECULAR STRUCTURE

It is queer how the molecular structure of some of the inhibitor molecules seems to influence their efficiency. Usually the size of the molecule, or rather the one with the larger negative half, is a much more efficient inhibitor than a smaller molecule. Also if you attach one organic material to the other and form a perfectly symmetrical structure, it is not nearly so efficient a coating as one which has an unsymmetrical or unbalanced structure. The only simile that can be drawn from this is that the molecule with the ungalanced structure, lays over and covers a bigger surface, or in shingle fashion, makes a more impervious coating.

Then again, in tacking these organics together, besides being careful which side you tack them on, you must be careful that you don't consume any of the spare bonds or valences of the elements which are supposed to hook onto the steel.

All of the inhibitors seem to contain certain elements which have variable valences. Valences, as you know, are the bonds or couplings with which an element hooks onto its brother elements in forming a compound. Hydrogen has one, oxygen has two, therefore, it takes two hydrogens to satisfy one oxygen in the formation of water, H_2O. These elements that I speak of in inhibitors with variable valences may have an optional 2 or 4 valences, while others have optional 3 or 5. Sulphur and oxygen are two of the elements of variable valence. Oxygen's most common valence is 2 but it has two other minor hooks or links with which it can grasp other substances. Sulphur is in the same class. Let's say we have a molecule in which sulphur is the positive part of the molecule and two of its bonds are attached to a large group of elements forming the negative side of the molecule. This large negative half of the molecule, gives the positive small half, a powerful positive charge. The molecule floating around in the acid solution suddenly gets into the flow of the current, and with a strong positive charge is attracted by the cementite or Fe_3C area. It has two available bonds, the unused portion of the sulphur bonds, and like a two-handed cordial hand-shake he grabs his old friend.

You can see from the above, why so many different possible arrangements of probably 5 elements into organic compounds, can produce such a variation in efficiency. One will have good coverage and won't stand heat, another will have strong attraction but won't have coverage, one may have attraction and coverage but a poor dielectric strength when put up against Bessemer or alloy steel.

There have been many investigations along inhibitor lines, some of these covering thousands of organic compounds, trying to establish some rhyme or reason toward the formulation of some definite working rule for an inhibitor.

RESEARCH

We might review a summary of some of the leading outside investigations leading toward collaboration of this theory which we believed and worked on as early as 1922. Discounting the red dog flour and other glutinous substances, we begin to come into the field of coal tar products with the early black chemical sludges. Formaldehyde, under the Holmes patent, was one of the first definite chemical patents which mentioned the composition of an inhibitor. The next was the Schmidt patent in 1926 mentioning thiourea. Following this there were many others showing that the field was just waking up.

In 1927, Chappell & Speller, in "Chemical and Metallurgical Engineering", published some curves showing that an inhibitor produced hydrogen over-voltages at the cathode areas. Hydrogen over-voltage is just another expression of cathode potential or resistance on the cathode surface. Chappel, Roetheli and McCarthy in "Industrial and Engineering Chemistry" in 1928 showed some curves showing the variation in cathode voltages against inhibitor concentrations.

At the spring meeting of the American Electro Chemical Society; Jimeno, Grifolli and Morral of Barcelona University, showed some curves exhibiting an increase in cathode voltage as the inhibitor concentration was increased. Excerpts from the abstract of their paper quotes as follows:

"The beneficial action of colloidal inhibitors depends on the adsorption of the inhibitor by the cathodic areas of the local cells or couples which are present on the surface of the metal. The assumption of the presence of such couples is supported by the presence of cathodic over-voltages and absence of anodic over-voltages. The higher iron oxides are reduced in spite of the presence of the inhibitor. The specific beneficial action of the inhibitor is the retardation of the evolution of hydrogen. There is a distinct parallelism between inhibitor action and hydrogen over-voltages."

They show curves between hydrogen over-voltage and milliamps per square centimeter. Their researches did not go into some of the more modern synthetically manufactured organics but they do show points as high as .6 and .7 of a volt before any infinitesimal quality of current begins to flow. This means that the inhibitor films which they tested have a puncture strength of approximately .6 to .7 volts.

Another quotation from the same paper is as follows:

"Accordingly we feel justified in concluding that the same selective adsorption of inhibitor obtained on the surface of the iron or steel being pickled without externally applied e.m.f. and that the cathodic areas will attract and absorb the colloidal particles, while the anodic areas will not. The ultimate over-voltage observed with current applied will be dependent upon the relative number of the cathodic areas protected or covered by the inhibitor, and this in turn will depend on the charge on the inhibitor particles, and its concentration in the bath."

"We have found upon adding an inhibitor to a pickling bath, its action is not immediate. A time interval of several minutes passes before the inhibitor attains its maximum effectiveness. This maximum will be different for different inhibitors, and the minimum concentration of inhibitor required will also be different for different inhibitors. There are two phenomena taking place, one opposing the other; there is a tendency for the inhibitor particles to be attracted to the cathodic areas on the iron surface; and, on the other hand the discharge in evolution of hydrogen tends to oppose the adsorption of the inhibitor particles. After a few minutes, the adsorption phenomena predominates. A thin, minimum layer of inhibitor has been deposited, and as the time proceeds the film becomes thicker.

It is at the cathode areas where atomic hydrogen is discharged. However, in the presence of the absorbed film of inhibitor, it becomes increasingly difficult for two atoms of hydrogen to combine to form molecular hydrogen. In other words, the inhibitor interferes with the reaction to form hydrogen molecules and hydrogen gas."

Mr. H. C. Munger of the American Rolling Mill Co. has computed the differences in potential between iron and the various iron oxides. He calculates that the difference in potential between iron and Fe_3O_4 is 1.42 volts. The other scales versus iron are less. Quoting from his summary, "The solution of scale on iron in an acid solution gives an electrolytic cell with comparatively high voltage. Organic inhibitors are adsorbed on a negatively charged cathode area of the iron, after the scale has been removed, and eliminate hydrogen evolutions by their change of the interfacial resistance, and their specific effect on the discharge of hydrogen ions, the mechanism of which is not entirely understood."

Prof. Charles A. Mann, Chief of the Division of Chemical Engineering, University of Minnesota, shows the relative effect of some similar organic structures coupled with their power as inhibitors.

In referring to inhibitors in the conclusion, "This positive ion attaches itself to the cathodic areas of the metal immersed in an electrolyte and forms a protective blanketing layer. The structure of the ion determines the packing of the ions in the layer which determines the imperviousness to hydrogen ions. The character of the radicals, the number and lengths of chain, the position of substituents on ring compounds and particularly the *stereo-chemical* arrangement are determining factors in the efficiency and amount of inhibitor necessary for various inhibitors in acid corrosion."

He has tested some 150 organic compounds.

He shows by curves using similarly related organic compounds how by the increase in the size of the molecules the effectiveness of the inhibitor is increased. Also, the stereo-chemical arrangement, that is, whether the molecule is symmetrical or unsymmetrical, has a lot to do with the inhibitor efficiency.

CONCLUSIONS

Summation of Good Inhibitor

We might go back now and review the requisites of a good inhibitor.

It must be easily soluble in dilute acid solutions, must leave no oily, tarry or scummy deposit on top of the bath.

It must be strong, and have a moderate cost compared to its strength.

It must not break down due to heat, either at high temperatures or long exposures at moderate temperatures.

It should have a strong attachment charge, so that it has a great affinity for the steel exposed, and so that it clings tenaciously through the boiling action of the bath after attachment has taken place.

It should have a high dielectric strength, that is, be impervious and non-porous.

It should not leave an oily or staining film on the sheet.

The dielectric deposit on the slight cathode areas should be easily removable, in the rinse water when the electrolyte potential is absent, or should easily clean off or burn off in subsequent operations.

DISCUSSION....LUBRICATION OF STEEL MILL EQUIPMENT

(Continued from page 19)

Turning to anti-friction bearings, Mr. Klein states that a ball bearing will not satisfactorily operate with a fibre grease. The advances which have been made in the manufacture of greases over the last three or four years have been so outstanding that I believe his statement should include his understanding of what is meant by a fibre grease. It is true that practically all straight soda soap greases have been known in the past as fibre greases. It is practicable, however, today by means of improved methods of manufacture to obtain a grease very much akin in its appearance, consistency and texture to a straight lime soap grease, yet with the temperature resisting properties of a soda soap grease and, furthermore, a high degree of resistance to water-solubility at normal temperatures. In the selection of a grease for any type of ball or roller bearing, the most careful consideration should be given to the operating conditions. Bearings of this type, as manufactured today, are most precise in their design and construction. They are, furthermore, very carefully protected against entry of contamining non-lubricating foreign matter. One must, therefore, consider the loads to be carried, the operating speeds and the probable temperatures within the bearing elements themselves.

H. R. Gilchrist: I have enjoyed Mr. C. J. Klein's Article "Lubrication of Steel Mill Equipment" very much and hope that by discussing some of our conditions it may help others as Mr. Klein's article has helped me.

Steam Turbines—We have found it a good practice to have two batches of oil for use on our large Turbines, one to be resting while the other is in service. We do this by having an extra tank with two compartments, the rested oil going back in service through a centrifuge separator. We also clean our system semi-annually with steam pressure.

Ring Oiled Bearings—We had some difficulty with a large mill drive motor bearing throwing oil in the windings. The ring was too wide and carried more oil than the grooving could handle, we put in a narrow ring and cut larger grooves in the bearings, thus eliminating the trouble. The windings are now dry and the bearings well lubricated.

Heavy Duty Bearings—We have made a very extensive study of roll necks and roll neck bearings and find that it pays us to keep our roll necks in the best condition. On composition bearings we grind all roll necks and keep them polished. On all stands in close range of high pressure sprays and scale breakers we use scale guards to keep the scale out of the bearings. We do not chamfer the bearings as this gives the scale a place to start to cut and is not needed for water. If there is enough water to keep the neck cool it will lubricate. All this in turn gives a longer life to the bearings and less scrap on the starting of an order and can hold order to closer tolerance.

Automatic Grease Systems—Our automatic grease systems are all set up with a filter in the line between the barrel pump and the system, which keeps all foreign matter out of the system.

S. A. Newman: I have read with keen interest Mr. C. J. Klein's article on "Lubrication of Steel Plant Equipment." Mr. Klein has certainly uncovered many of the lubricating problems that confronted all steel mill operators and his suggested methods for solving them will be useful to all operating men who have the opportunity of reading his article.

In commenting on his treatment of prime movers, I may add that the condition he found in the oiling system of the 6000 K.W. Unit was not uncommon. The methods Mr. Klein used to overcome the difficulty for this type of an oil system were very good.

Some turbine operators have discovered by checking the neutralization number of the oil they have found the point where an oil will start dropping out and depositing the oxidized oil held in suspension. If the oil is changed at this point it will not be necessary to take the piping off and clean out the system. By flushing with an inexpensive Flushing Oil any sludge that may be in the system will be picked up by this oil rather than the new lubricant to be installed in the system.

There is considerable research going on at present to ascertain the effect of metals found in a turbine on the neutralization number of the oil in the system and it has been developed that certain metals exhilarate oxidation materially.

Mr. Klein can be highly complimented on his recommendations for air operated tools. Line oilers will pay for themselves many times in maintenance cost savings on the air equipment, especially if a properly compounded oil is used that will stand the washing effect of the water which will be present in compressed air.

Many operators of air compressors are using oil of too high viscosity for the lubrication of air cylinders. Better success can be obtained by using an oil fairly low in viscosity as well as using it sparingly as suggested by the author.

Constant level oilers, which Mr. Klein mentioned for holding proper level in ring oil bearings are being used successively to keep oil at the proper level in crank cases of steam and gas engines.

Under circulating systems the author mentioned demulsification characteristics of heavy viscosity oils. It is true oils of very good demulsibility can be procured, but this is not the correct method of determining the quality of an oil. If the demulsibilities of these heavy oils are checked after they have been in the system a short time they will be found to be practically zero.

Some of the bearings that are being used in our modern mills are far more accurately made than those found in a steam turbine and a quality oil is essential.

Rather than try to purchase oils on a rigid specification that is practically meaningless, I believe it would be advantageous to the mill operators to place the responsibility on a reputable oil company to furnish an oil that would take care of their equipment.

Items of Interest

J. Thomas Barclay has been appointed chief metallurgist of the Carnegie-Illinois Steel Corporation, Vandergrift Works. Mr. Barclay began his service with the United States Steel Corporation at the Vandergrift Works on February 1, 1912, in the metallurgical department, and advanced by promotion through various grades until promoted to assistant chief metallurgist on January 1, 1926, in which capacity he served to date.

Edgar Marburg to be assistant chief metallurgist. Mr. Marburg graduated from the University of Pennsylvania in 1917 with the degree of B. S. in C. E. He entered the U. S. Army in August, 1918; discharged 1st Lt. Corps of Engineering, in October, 1924. Entered the employ of the Aluminum Company of America, until September, 1925, when he entered the Massachusetts Institute of Technology for Post Graduate work. Received the degree of M. S. in 1926, and entered the employ of the Jones & Laughlin Steel Corp., where he was employed until 1928 when he entered the employ of the Vandergrift Works as a metallurgist, serving in that capacity to date.

Saylor C. Snyder to be chief inspector. Mr. Snyder graduated from Pennsylvania State College as an Electrical Engineer. He was employed by the Pittsburgh Electric Furnace Corporation as Assistant Electrical Engineer from 1927 to September 1, 1928, when he entered the employ of the Vandergrift Works, where he has been connected with production of electrical sheets to date.

▲

Frederick E. Warr has been appointed chief of safety Bureau, Pittsburgh district, Carnegie-Illinois Steel Corporation.

Mr. Warr is a graduate of the Washington High School and attended the University of Pittsburgh Night School. He entered the service of the United States Steel Corporation in 1906 as a clerk at the lower Union Mills of the Carnegie Steel Company at Pittsburgh. In 1914, was promoted to chief order clerk; from 1920 to 1924 was foreman of the Forge Department; in 1924 was transferred to the McCutcheon Mills as assistant to chief clerk; in 1928 was transferred to the safety department, general offices of the Carnegie Steel Company and served as secretary to the general safety committee to date.

▲

Thomas J. McLoughlin has been appointed as assistant to J. E. Lose, vice president in charge of operations, Carnegie-Illinois Steel Corporation, effective November 1st.

Mr. McLoughlin's service with the United States Steel Corporation began at the Duquesne Steel Works of the Carnegie Steel Company in 1913 as an engineer apprentice. His services have been continuous, and he had been fuel engineer at the Duquesne Works from 1924 to January, 1936. At that time he was appointed assistant to W. C. Oberg, manager of operations for the Pittsburgh District.

He graduated from the Stevens Institute of Technology with the degree of mechanical engineer, class of 1913.

▲

Effective November 1, 1936, the following changes in Blast Furnace Organization were made by the Carnegie-Illinois Steel Corporation.

W. H. Burnett, superintendent, blast furnaces, Clairton Works, will be transferred to assistant superintendent, blast furnaces, Ohio Works.

William Stewart, assistant superintendent, blast furnaces, Edgar Thomson Works, will be transferred to Superintendent, blast furnaces, Clairton Works.

T. G. Ayers, assistant superintendent, Isabella Furnaces, will be transferred to assistant superintendent, blast furnaces, Edgar Thomson Works.

▲

Effective November 1, 1936, the following changes were made in the Open Hearth organization of the same company.

J. THOMAS BARCLAY

FREDERICK E. WARR

THOMAS J. McLOUGHLIN

WILLIAM CORDES SNYDER

FRANK O. LEITZELL

E. F. ENTWISLE

R. Urquhart, superintendent, open hearth No. 3, Homestead Works, will be transferred to assistant superintendent of the entire open hearth organization at Homestead Works.

F. R. Smith, superintendent, open hearth department, Clairton Works, will be transferred to superintendent, open hearth No. 3 Homestead Works.

W. F. Davis, assistant superintendent, open hearth department, Clairton Works, will be transferred to superintendent, open hearth department, Clairton Works.

▲

William Cordes Snyder, Jr., new vice-president and manager of roll sales of Lewis Foundry and Machine Company of Groveton, Pa., was born June 12, 1903 at Snow Shoe, Pa.

William Cordes Snyder, Jr., was educated at Bellefonte Academy, Army and Navy Preparatory School of Washington, D. C., Harrisburg Academy and supplemented by a mining engineering course at Lehigh University, being an Alumnus of the class of 1925.

Shortly after his collegiate career, he went to work for the Wheeling Mold and Foundry Company at Wheeling, W. Va., serving a two year apprenticeship in charge of the chemical laboratory. In 1927 he associated himself with the Lewis Foundry and Machine Company as a metallurgist and roll maker and has been continuously identified with the Company to the present time. On October 16, 1936 he was elected vice-president in charge of roll sales, and devotes his exclusive time to the duties of that office.

▲

Frank O. Leitzell, new vice-president in charge of machinery sales of the Lewis Foundry and Machine Company, Groveton, Pa., was born March 24, 1887 at Washington, D. C.

Mr. Leitzell received his education at the public and high schools in Washington, D. C., supplemented by a course at Pennsylvania State College, graduating therefrom in 1907 with the degree of B. S. in mechanical engineering.

Shortly after his collegiate career, he went to work for the American Locomotive Company in Pittsburgh, where he served a special two year apprenticeship. His next position was with H. K. Porter Company, Pittsburgh in the designing department and at the time he left the Company in 1919 he was assistant general manager of the Company. In 1919 he accepted a position with Blaw-Knox Company as sales manager in the welding department and remained there until June 1935, when he became sales manager of the machinery department of Lewis Foundry and Machine Company. On October 16, 1936 he was elected vice-president of the company in charge of machinery sales, to which duties he will devote his exclusive time and attention.

▲

E. F. Entwisle, assistant general manager of Lackawanna Plant of Bethlehem Steel Company, since early this year, has been appointed general manager to succeed Mr. Timothy Burns, who retired due to illness. However, Mr. Burns will continue with Bethlehem Company in an advisory and consulting capacity.

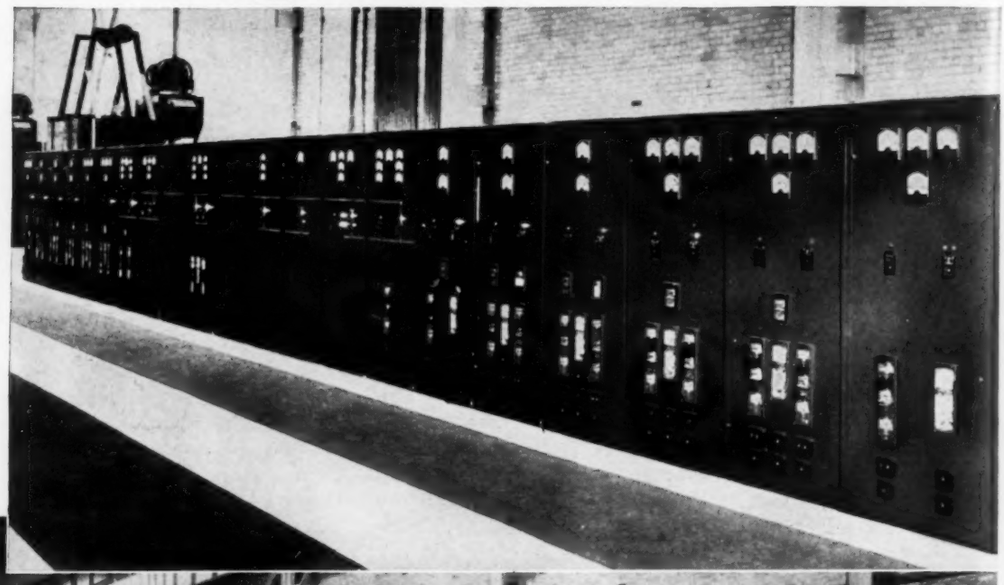
Mr. Entwisle was formerly superintendent of the Saucon Division of the Bethlehem Plant. He was graduated from Cornell University in 1906, and entered the employ of Bethlehem Steel Company, at the Maryland plant, Sparrows Point, Md., as mechanical engineer in 1914. He later became successively mechanical engineer at Steelton Plant, general superintendent of the then blast-furnace division of Lebanon Plant, and assistant general manager of Steelton Plant. He came to Bethlehem Plant as superintendent of the Saucon Division in 1928.

▲

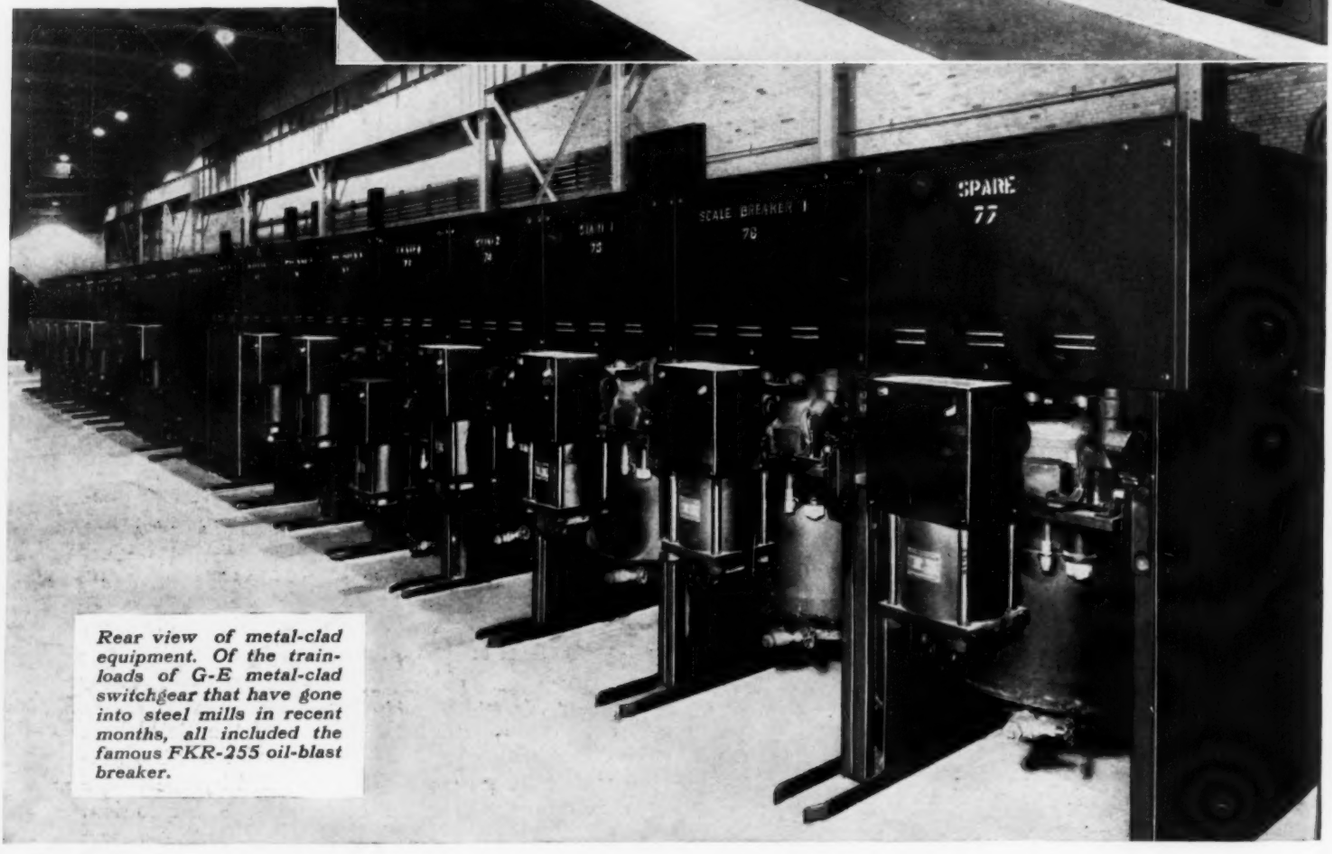
J. C. Reed, electrical engineer of the Bethlehem Steel Company, Steelton, Pennsylvania, was the winner of a matched set of irons awarded by the Gatke Corporation, at our last Iron and Steel Exposition.

These irons were awarded for guessing the nearest combined tonnage of steel actually rolled by two Gatke Non-Metallic Moulded Bearings displayed at our exposition. Mr. Reed's guess was 500,498, tons, while the actual tonnage was 500,379.

The Lengthening



Front view of the metal-clad equipment below, showing semiflush mounting of instruments and devices — practically the steel mills' standard



Rear view of metal-clad equipment. Of the trainloads of G-E metal-clad switchgear that have gone into steel mills in recent months, all included the famous FKR-255 oil-blast breaker.

G E N E R A L

Roll—

1934 A hot-strip mill in Youngstown

1934 A cold-strip mill in Youngstown

1935 A blooming mill in Pittsburgh

1935 A hot-strip mill near Buffalo

1935 A cold-strip mill in upper Ohio Valley

1935 A hot-strip mill near Detroit

1935 A cold-strip mill near Baltimore

1936 A hot-strip mill in Pittsburgh

1936 A cold-strip mill in Pittsburgh

1936 A rod mill near Chicago

1936 A semicontinuous plate mill near Pittsburgh

1936 The Latest Job — 48 units for a large power house in the Monongahela Valley—

All 500,000-kva General Electric metal-clad switchgear. Shipped assembled—received complete, ready to operate

RENEWED and conclusive evidence that General Electric metal-clad switchgear is the accepted mill standard

G.E. BUILDS WITH STEEL

880-13

ELECTRIC

GEORGE H. BUCHER

ALFRED E. GIBSON

George H. Bucher was elected executive vice president of the Westinghouse Electric & Mfg. Company with headquarters at Pittsburgh, Pennsylvania. Mr. Bucher is also president and general manager of the Westinghouse Electric International Company.

Mr. Bucher has been connected with the Westinghouse organization since September 1, 1909. After graduating from Pratt Institute, Brooklyn, in both steam and machine design and also electrical engineering, Mr. Bucher joined the Westinghouse Electric and Manufacturing Company at East Pittsburgh as a graduate student. In 1911 he was transferred to the Export Department in New York.

In 1920, he was appointed assistant to general manager of the Westinghouse Electric International Company, and a year later, 1921, he was made assistant general manager, which position he held until 1932, when he was elected vice president and general manager. In 1934 he was elected president and general manager of the same Company, and in 1935 he was elected vice president of the Westinghouse Electric and Manufacturing Company.

▲

Alfred E. Gibson, executive vice president, Wellman Engineering Company and member of our society, was elected president of the American Welding Society.

Mr. Gibson was graduated from the Ohio State University, mechanical engineering, 1909. Employed by the Wellman Engineering Company since graduation. After two years work was made superintendent of shop, and later became general superintendent in charge of Cleveland and Akron Works.

In 1926 became associated with Fulton Foundry & Machine Company as vice president and later president. In 1928 returned to Wellman as works manager, later being made vice president in charge of engineering and shop production. Mr. Gibson is also a director of his company. In 1935 he was appointed executive vice president.

WANTED—Steel Mill Designer and Engineer. Plant layout and general designing experience essential. Long established mid-western concern. Permanent position. Salary $250 to $350. Write giving full details, experience, education, etc. Write "A A"—1010 Empire Building, Pittsburgh, Pa.

▲

Died

J. H. Hartsuff, who retired on September 30, 1933, after 49 years of continuous service with the United States Steel Corporation subsidiaries in the Pittsburgh District, died November 5 at his home in New Castle, Pa.

Mr. Hartsuff was general superintendent of the Edgar Thomson Works, Braddock, Pa., and a director of the Carnegie Steel Company, at the time he retired.

He died after a short illness of pneumonia.

He began his lengthy continuous employment record on May 5, 1886, as a machinist in the plant of the American Steel & Wire Company, in New Castle.

On November 2, 1892, he went to the Carnegie Steel Company, at New Castle, remained less than a year, then transferred to American Sheet and Tin Plate Co., at New Castle, for a brief stay of about six weeks before returning to the Carnegie Works.

Mr. Hartsuff changed to American Sheet and Tin Plate again on July 19, 1896, but went back to Carnegie the following March 7th as rolling foreman, and in the ensuing 21 years held the positions of superintendent and assistant general superintendent.

In April, 1918, he became superintendent of the Farrell Works of the Carnegie Steel Company, and two years later was made general superintendent of the Edgar Thomson Works.